Statement before the

U.S. Senate Committee on Environment & Public Works

Opportunities in Industrial Decarbonization: Delivering Benefits for the Economy and the Climate

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Chairman Carper, Ranking Member Capito, and Members of the Committee:

Thank you for the opportunity to appear before you today to discuss the benefits and opportunities of industrial decarbonization.

My name is Abigail Regitsky, and I am a Senior Manager on the U.S. Policy and Advocacy team at Breakthrough Energy, a network founded by Bill Gates of investment funds, nonprofit and philanthropic programs, and policy efforts working together to scale the technologies we need to achieve net-zero emissions by 2050. Following eights years of dedicated work since the creation of Breakthrough's first initiative, this week we published our first State of the Transition Report to share the progress being made across every major sector of the economy and the challenges that remain ahead. Industry—or what we call the Manufacturing Grand Challenge—features prominently in the Report, and I look forward to sharing our thoughts on this critical issue today.

Innovation is at the heart of Breakthrough Energy's mission and theory of change, and more than any other sector, industry cannot decarbonize without innovation. So, before detailing our approach to industrial decarbonization, it is informative to share our approach to innovation. Above all, we view innovation as the only path to achieve net-zero emissions while also delivering clean, affordable, and reliable energy and goods to support a high standard of living for all people around the world. In particular, innovation will help us lower, and eventually eliminate, the green premium—the additional cost of using a clean technology over a more emissions-intensive option. We aim to accelerate the innovation cycle through a combination of **investments** throughout technology lifecycles and smart, market-friendly public and private sector **policies**.

Breakthrough Energy has three flagship programs that make investments along technology discovery, development, and deployment.

Breakthrough Energy Fellows is a technology focused incubator program, which supports early-stage entrepreneurs to take their climate discoveries out of the lab. In addition to these Innovator Fellows, we support Business Fellows with extensive industry experience to advise Innovator Fellows in developing their technologies and building their businesses. Through two cohorts over the last two years, we have supported 63 Fellows, across 38 projects and 11 countries, in several areas critical to industrial decarbonization.

Breakthrough Energy Ventures (BEV)—the first initiative in the Breakthrough network—is a venture capital firm that invests only in technologies that have the potential to reduce emissions by 500 megatons per year, roughly one percent of annual global emissions. Unlike other venture capital firms, BEV is highly technical, deploys patient capital, and is comfortable taking enormous risks to help startups further develop their technologies and companies for commercialization. Over the last six years, BEV has invested nearly $2B in over 100 companies, many of which are developing game changing technologies to decarbonize industrial heat, cement, and steel, among others.

Breakthrough Energy Catalyst deploys capital to support first-of-a-kind commercial scale projects to help derisk new climate technologies and overcome the final "valley of death" of technology innovation. Catalyst works with climate tech companies to advance their projects from development to funding and ultimately, to construction. Once derisked, it will be easier for the next project to attract funding from traditional infrastructure investors, which will be needed for a technology to scale. This year, Catalyst added manufacturing as an area of focus for project selections.

Alongside these investment initiatives, Breakthrough Energy's policy teams work with government, private sector, and civil society partners to enact policies that accelerate innovation at every step and ensure markets around the world are primed for new clean technologies. I will spend the bulk of my testimony covering Breakthrough's U.S. policy framework to accelerate industrial decarbonization.

Overview

The industrial sector is responsible for transforming raw materials into major components necessary to our daily lives: the cement in our buildings and bridges, the steel in our cars and appliances, the clothes we wear, the books we read, the plastic containers that keep our food and drinks safe and fresh. It has been the engine of American economic development and will continue to drive progress in emerging economies around the world. It also accounts for nearly one fourth of U.S. greenhouse gas (GHG) emissions and about one third of global emissions. While sectors like power and transport are expected to continue reducing emissions over the next decade, industrial emissions are likely to stay flat and could even increase, making it the top source of U.S. emissions in the future if current trends hold. Unlike areas like clean electricity, building efficiency and electrification, and light-duty transportation, the majority of technologies necessary to decarbonize industry still need to be developed and commercialized, and a robust policy framework has been lacking. Industry will require ample technological innovation and the right policies to accelerate innovations from lab to market to widescale deployment to achieve net-zero emissions by midcentury.

Breakthrough Energy recognized this gap several years ago, first through the launch of BEV and subsequent investments into emerging technology companies tackling industrial emissions, followed by complementary work to advance industrial sector policies to support technology innovation and commercialization. Since then, the debut of increasing country and corporate net-zero commitments has forced deeper consideration of the role of the industrial sector in achieving these goals, and we have seen increased interest from policymakers, companies, philanthropy, and civil society on the issue. While achieving a net-zero industrial sector will be difficult, the progress of the last few years only boosts my confidence and optimism that it is a challenge we can and will overcome through public and private sector collaboration and where American innovation is poised to lead.

In my testimony, I will briefly cover:

- Industrial decarbonization challenges and benefits
- Technological solutions, with a focus on cement and steel
- Policy progress and opportunities

Industrial Decarbonization Challenges and Benefits

The industrial sector accounted for 23% of U.S. GHG emissions in 2021. When emissions from the generation of electricity are divided into end-uses, industry accounted for 30% of emissions, tied with buildings as the largest emitting U.S. sectors.[1] Cement, iron and steel, and chemicals and refining are the big three industrial emitting sectors, accounting for about 70% of CO_2 emissions from industry globally and nearly 50% of industrial emissions in the United States.[2] Industry has a reputation of being "hard-to-abate," largely because the main sources of emissions are intrinsic to how industrial goods are manufactured today: emissions from heat (principally delivered through the combustion of fossil fuels) and process emissions from the chemical reactions necessary to transform raw materials to usable products. These are the primary technical challenges facing industry, which will require innovations in using less heat and non-emitting heat sources, as well as developing completely new ways of industrial production that avoid heat altogether and use new feedstocks to eliminate CO_2 as a byproduct. And while these challenges are common across industrial sectors, the diversity of products and processes under the industry umbrella means that each sector will often need unique solutions to these challenges, emphasizing the importance of robust innovation support for each sector. Additional challenges for the industrial sector include high capital costs for decarbonization improvements and clean greenfield facilities, long asset lifetimes with minimal downtime, low profit margins, and significant trade exposure. These multiple challenges will be difficult to overcome, but American ingenuity is up to the task and the solutions uncovered will present benefits beyond climate progress alone.

On average, U.S. industry already boasts lower emissions intensity production than many of its foreign counterparts, giving America a "carbon advantage" compared to many of its trading partners. Meanwhile, in 2019, the United States imported more than 1.2 gigatons of embodied emissions—larger than any other country, with the greatest portion coming from China—showcasing the significance of traded emissions, or the "carbon loophole." These phenomena offer a unique opportunity: strengthen the U.S. carbon advantage while closing the carbon loophole. As the United States rightfully aims to reduce emissions within its borders, using smart policies to address imported emissions will not only properly account for and reduce the emissions from U.S. consumption, but it will also ensure that domestic investments in decarbonization reward American manufacturers with an increasing domestic and global market share for cleaner goods. For example, a 2022 Boston Consulting Group (BCG) study projected ~$11T in global clean steel sales through 2050, with the U.S. domestic market reaching ~$30B in 2050—double the net income of U.S. steelmakers in 2022.[3] Another study found that adopting a U.S. border carbon policy could help domestic steel and aluminum producers increase their annual revenues by $8.5B and $6B, respectively, by 2030.

Addressing industrial emissions will also safeguard manufacturing's role as a critical piece of the U.S. economy. In September 2023, the manufacturing sector employed 13 million Americans, and for every one manufacturing worker, 4.4 workers are added to the economy overall.[4] Thus, investing in this sector will pay dividends in economic and job growth. It is also an opportunity to reinvest in deindustrialized areas of the country, where manufacturing jobs have declined over the last several decades. For example, the same BCG study estimated the creation of ~30,000 average annual jobs from possible investments in clean steel through 2050. As industries evolve

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[1] U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021 (April 2023).
[2] U.S. Department of Energy, Pathways to Commercial Liftoff: Industrial Decarbonization (September 2023).
[3] U.S. International Trade Administration, U.S. Steel Executive Summary (2023).
[4] National Association of Manufacturers, Facts About Manufacturing (2023).

to new forms of clean manufacturing, it will be important to make sure the existing and future workforce has the skills necessary to fulfill this employment potential.

In addition to the direct economic and jobs benefits of industrial decarbonization, cleaning up industrial processes will also bring health benefits for the workers in industrial factories and the fence-line communities surrounding them. Along with GHG emissions, industrial production releases criteria air pollutants (e.g., particulate matter (PM), sulfur dioxide, nitrogen dioxide), as well as hazardous air pollutants and toxic air, land, and water pollutants. A recent study focused on the U.S. iron and steel, cement, aluminum, and metallurgical coke industries estimated that elimination of PM emissions and its precursors could avoid 1,250 to 2,830 deaths each year. It also estimated reductions in the occurrence of respiratory and cardiac events, related hospital admissions and emergency room visits, and lost workdays. Converting fossil fuel combustion to clean heat sources will play a significant part in reducing these criteria air pollutant emissions, but many are attributed to the industrial processes themselves. As entrepreneurs develop completely new ways of making industrial goods, there will be an opportunity to ensure that new designs reduce or eliminate these emissions as much as possible.

To secure these multiple benefits from industrial decarbonization, the government must play a leading role in helping manufacturers overcome the many challenges that stand in their way. As with any new technology, there will be technical and financial risks that the private sector cannot bear alone, where public investment must fill the gap and be comfortable with taking measured risks. Industrial decarbonization also presents the opportunity of public and private sector collaboration (e.g., existing manufacturers partnering with startups that provide technology solutions), where multiple entities can share the overall risk burden. With smart, transparent policies, these risks can be mitigated but not entirely eliminated. Innovation is inherently a feedback loop of progress, failure, learning, and eventual success, and no steps can be skipped. Alongside innovation support, industrial policy can help ensure favorable market conditions for technology adoption, such as seeding demand for clean industrial goods at home and abroad.

Technological Solutions

Despite the heterogeneity among industrial subsectors, there are common cross-cutting technology solutions that could be applied in multiple subsectors to reduce emissions and are necessary to achieve emissions reductions in an economically and technologically feasible way. The exact applications and extent to which these technologies will be deployed in each subsector will vary, and there may be trade-offs and competition between subsectors for technologies with potential resource constraints. With that in mind and roughly mirroring the decarbonization pillars identified in the Department of Energy's (DOE's) Industrial Decarbonization Roadmap, industry should generally pursue these technological approaches in the following order:

- **Energy and materials efficiency and circularity**: Reductions in energy and material waste through process efficiency gains, circular approaches, including demand reduction;
- **Electrification**: Electrification of industrial production processes and heat sources;
- **Hydrogen (and other zero-carbon fuels and feedstocks)**: Producing and utilizing zero-carbon chemical energy sources like hydrogen; and
- **Carbon management:** Capturing carbon to prevent unavoidable carbon emissions from release, removing carbon dioxide from the atmosphere, and safely storing or utilizing captured and removed carbon.

In general, **energy efficiency** solutions should be maximized, as they reduce overall energy use and therefore minimize system costs. Traditional energy efficiency measures include upgrading to more efficient equipment, utilizing waste heat, combined heat and power, and other process-specific solutions. Increasingly, systems approaches, like strategic energy management and smart manufacturing, can yield further energy savings, as systems are electrified and digitized. Importantly, investments in efficiency measures should consider the overall context of the energy transition and long-term emissions reductions to avoid lock-in of outdated technologies for short-term gains in efficiency (e.g., increasingly efficient fossil-fuel-based equipment and vehicles vs. electrification as the grid becomes cleaner).

Alongside energy efficiency, **materials efficiency and circularity** should also be maximized to reduce emissions and costs by minimizing the need for processing of raw materials and manufacturing finished goods. Typical options include efforts taken during the production process and at end of life (i.e., reducing, reusing, recycling, and remanufacturing). Opportunities that target other parts of the value chain can also be considered, such as increasing product lifetimes, increasing product utilization through new business models, and designing for efficiency and disassembly. In some cases, pursuing materials efficiency tools, such as certain types of recycling, could increase energy use and emissions, so it will be necessary to closely investigate potential trade-offs.

Electrification of industrial production methods and process heat across several subsectors can make a significant contribution to overall industrial decarbonization, but it will depend on the continued decarbonization of the grid, including sufficient buildout of new clean electricity generation and transmission. Technological options at different levels of maturity include industrial heat pumps, resistive heaters, electric boilers, and electric kilns and crackers. Commercialization of thermal energy storage (TES) technologies capable of leveraging variable power sources for industrial use will also be important. Many companies are developing TES solutions, with several commercial systems available for customer purchase.

Where electrification is not a viable option—for a range of technical and non-technical reasons bespoke to each project—**hydrogen** and carbon management offer optionality. Because hydrogen's production and use tends to be less energy efficient than direct electrification, and more energy efficient technology pathways will typically be lower cost and less land- and resource-intensive, the lowest-cost and most-resource efficient net zero pathways tend to use hydrogen in a targeted way—only where it is required as a feedstock, where energy dense fuels are needed, and in large-scale applications with high heat needs and high uptime requirements. Hydrogen can be used as a direct reducing agent of iron ore in lower emissions steelmaking processes, can serve as a source of high grade heat when combusted, and as a feedstock for a variety of chemical processes. To enable hydrogen's role in industrial decarbonization, it is critical to support innovation in both methods to cost-effectively produce clean hydrogen and ways to use the clean hydrogen in new industrial applications.

Similarly, **carbon management** will be necessary to achieve net-zero industrial sector emissions by midcentury, but it should be deployed only when other technological options have been exhausted or are not yet commercially available to realize near-term emissions reductions at a larger scale. With current mature capture technologies (e.g., amine-based chemical adsorption processes), the purer the CO_2 stream, the cheaper the cost of capture. For lower-purity CO_2 streams that are not yet profitable to capture, cost reductions can come from economies of scale and learning by doing, as well as innovation in new capture technologies and modularization.[5] For industrial subsectors with process and combustion emissions, separation of these sources (or elimination of combustion emissions through process heat decarbonization) can also yield high-purity process CO_2 streams that are more economical to capture. Once captured, the majority of CO_2 emissions will need to be safely and permanently stored for maximum climate benefit. In the industrial sector, utilization can also play a small but increasing role as a permanent storage solution, such as through building materials and plastics.

Sector-Specific Technologies

Net-zero modeling typically finds that different mixes of the cross-cutting industrial decarbonization approaches above can reduce most of the emissions for every industrial subsector. However, each subsector has other unique emerging technologies that may be able to reduce emissions more efficiently and affordably in the future but do not yet have clear costs established in the literature to enable widespread inclusion in models. Supporting these sector-specific technologies is critical to lowering green premiums beyond currently modeled net-zero pathways to improve the likelihood of emissions reductions being achieved in the U.S. and abroad. Below, I will provide some examples of specific solutions for two sectors: cement and concrete, and iron and steel, which are also featured in Breakthrough Energy's State of the Transition Report.

Concrete and steel are two of the most widely used materials in the world and comprise the two highest emitting industrial sectors globally. They are largely made using the same technologies that have been perfected over centuries to create the relatively cheap, abundant, strong, and low emissions-intensity structural materials the world relies on today. While there are some opportunities for material efficiency and material substitution in certain use cases to reduce individual project demands for concrete and steel, the need for more infrastructure buildout in emerging economies and to improve resilience in a changing climate means that these foundational materials are here to stay. Fortunately, several innovative technologies to decarbonize these industries are on the horizon, along with already commercial, scalable solutions that can provide reductions in the near-term. Different types of policies will be needed to accelerate development of pre-commercial technologies and uptake of commercial solutions, both of which will be critical to achieve net zero.

Cement and Concrete

Concrete is composed of aggregates (e.g., gravel and sand), water, and cement, which acts as the glue that binds everything together. Cement only makes up 10-15% of the concrete mixture but is responsible for ~90% of the emissions associated with concrete. To produce cement, limestone ($CaCO_3$), clay, and other raw materials are heated to nearly 1500°C, which drives the CO_2 from the limestone ($CaCO_3 \rightarrow CaO + CO_2$) and forms a cement intermediary, called clinker. This reaction is responsible for the vast majority of cement emissions due to the process emissions and high heat required. The clinker is then ground

[5] U.S. Department of Energy, Pathways to Commercial Liftoff: Carbon Management (April 2023).

with calcium sulfate and other additives to make cement.[6] Cement made from nearly entirely clinker is called ordinary portland cement (OPC).

This status quo provides five main categories for reducing emissions from concrete, which generally go from most to least commercially ready in the following order:

- Use less concrete in construction
- Use less cement in concrete
- Use less clinker in cement
- Decarbonize clinker production
- Use decarbonized alternative cement chemistries

Use less concrete in construction

This involves avoiding over-designing and over-building with concrete to meet sufficient structural performance requirements with less material. It could also include substituting concrete with other building materials where possible, such as timber.

Use less cement in concrete

It is possible to use less cement in concrete by adding supplementary cementitious materials (SCMs) to a concrete mix, which could decrease the cement content to 5% or lower. Traditional SCMs already in use by industry include fly ash (a byproduct of coal combustion) and steel slag (a byproduct of the traditional steelmaking process).[7] These should be used as much as possible, but their supply will be limited as the processes they rely on continue to decline. To solve this problem, one company is creating engineered SCMs from relatively abundant raw materials available close to existing concrete supply chain infrastructure. Their first commercial production facility is set to break ground in Texas in 2024. Cement content can also be lowered by optimizing other parts of the concrete mixture, such as using a size gradient of aggregates to allow for better distribution throughout the concrete without additional binder.

Use less clinker in cement

SCMs can also help use less clinker in cement by being blended directly with clinker to produce blended cements. On average around the world, cements contain ~70% clinker.[8] Portland limestone cement (PLC) is a common blended cement used in the United States for over a decade, which blends up to 15% limestone with clinker to achieve up to 10% CO_2 reduction. A newer blended cement involves grinding limestone and calcined clays with 50% clinker to produce cement with up to 40% fewer emissions. Another company uses proprietary admixtures to enable use of optimized SCM cement blends with clinker content as low as 25%.

[6] U.S. Department of Energy, Pathways to Commercial Liftoff: Low-Carbon Cement (September 2023).
[7] National Concrete Pavement Technology Center, Cementitious Materials.
[8] International Energy Agency, Cement.

Decarbonize clinker production

While the above strategies can dramatically reduce the embodied emissions of concrete, getting to net-zero emissions requires decarbonizing clinker production, which can be accomplished through two main options. One option involves adjustments to the current production method by using a combination of cross-cutting technologies: decarbonizing the heat source required for calcination through electrification or low-carbon fuels and using carbon capture on the now high purity stream of process emissions. One company is attempting to do this using an indirectly heated kiln and already has projects with multiple partners around the world. Either decarbonizing heat or carbon capture alone could also be adopted separately to reduce emissions, but it would likely not result in full decarbonization. The second option is to develop entirely new ways of producing clinker to avoid emissions. One company is developing a method to make clinker from calcium silicate rocks, a noncarbonate raw material that will not release CO_2 in its processing. They recently received third-party certification that their cement is identical to standard OPC, confirming their product as a drop-in replacement for much of the cement used today. Another company is developing an electrochemical process for producing clinker, which would increase the CO_2 stream purity while reducing the overall amount of CO_2 byproduct, enabling easier pairing with carbon capture.

Use decarbonized alternative cement chemistries

Alternative cement chemistries involve using non-clinker-based binders for cement. There are a wide variety of different chemistries being developed and in use in small segments of the market today, but they are unlikely to scale without wider adoption of performance specifications, where projects are not required to follow traditional cement and concrete recipes. One example is a company using noncarbonate feedstocks and industrial wastes to electrochemically produce a reactive calcium- and silicate-based cement that meets the existing performance specification for hydraulic cements. Another company creates non-hydraulic calcium silicate cement that cures with CO_2 instead of water.

Bonus pathway: carbon storage

In addition to eliminating the emissions from cement production, the non-cement components of concrete can also be used to permanently store carbon, creating a potential revenue stream for captured carbon (from cement and other industrial processes, as well as direct air capture) and the possibility of carbon-negative concrete. One company combines captured CO_2 with calcium from waste sources to produce synthetic limestone aggregate.

Iron and Steel

At its most basic elements, steel is an alloy of iron and carbon. There are three general steps required to turn mined iron oxide ore into steel: reduction of the iron oxide into metallic iron (ironmaking), separation of ore impurities, and alloying with carbon and other minor elements to produce steel (steelmaking).[9]

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[9] World Steel Association, The steelmaking process.

There are two main technologies for ironmaking in use today: blast furnaces (BFs) and direct reduced iron (DRI). BFs melt and reduce iron ore with metallurgical coal, reaching temperatures of up to 2300°C, to produce pig iron. In the melt state, ore impurities separate from the pig iron into slag, which can then be used in other industries (i.e., SCMs for cement and concrete). DRI involves reducing iron ore without melting and can use a variety of fuels/reductants (e.g., natural gas, coal, biomass, hydrogen) at temperatures below 1200°C. Natural gas is the most common DRI fuel used in the U.S. today. This lower temperature process is more energy- and emissions-efficient than BFs, but the lack of a melt stage leaves impurities in the DRI, requiring the use of only high purity ore, beneficiated ore, or an additional melting step (all adding increased costs) to achieve the same level of purity as pig iron. Ironmaking accounts for the majority of emissions in the overall steelmaking process, due to the high temperatures (delivered through fossil fuel combustion) and use of carbon as a reducing agent to remove the oxygen from iron oxide, forming CO_2.

There are also two main ways to make steel today: basic oxygen furnaces (BOFs) and electric arc furnaces (EAFs). BOFs take melted pig iron from BFs combined with some steel or iron scrap and use pure oxygen to melt the scrap, adjust the carbon (and other elemental) content of the pig iron and further remove impurities. EAFs largely recycle steel scrap by melting the scrap in electric furnaces and adjusting the steel composition through the addition of pig iron or DRI and other elements and reduction via oxygen. Primary steelmaking often refers to processes that turn iron ore into virgin steel (e.g., BF-BOF, DRI-EAF), while secondary steelmaking (i.e., EAF only) recycles scrap steel (with some primary steel input) into new steel products. Secondary steelmaking is significantly less emissions intensive than primary steelmaking, with the main source of emissions coming from the electricity used to power the EAF.

With multiple current steelmaking pathways, there are many options for reducing emissions, but they broadly fall into the following categories, again roughly going from most to least commercially ready in the following order:

- Use less steel in products
- Use more secondary steel
- Decarbonize current steelmaking processes
- Develop new net-zero primary steel production processes

Use less steel in products

As with concrete, using less steel involves avoiding over-design and over-building with current products and potentially developing new, better-performing steel alloys that enable even further material efficiency. There are also opportunities for material substitution in certain applications (e.g., aluminum or composites).

Use more secondary steel

This would minimize the need for primary steelmaking, which is responsible for the majority of steelmaking emissions. The ability to do this will depend on two factors: scrap steel availability and impurity management. Almost all steel is already recycled, and as more and more primary steel products reach end-of-life, this will naturally inject more scrap steel into the market, though with large geographical imbalances in availability. For example, in a developed economy like the United States, secondary steelmaking already accounts for 70% of steel production and all scrap is exhausted.

The second constraint is impurities, which increase in concentration as scrap is recycled again and again and is the reason why EAFs still need some pig iron or DRI to add to scrap. This currently limits recycled steel from use in applications that need higher quality steel, such as automobiles and defense. Overcoming the impurity problem in recycled steel will be critical, requiring innovations in separations technologies and steel forming processes that can handle higher impurity levels. One company is trying to do this by designing a hot-rolling fabrication alternative, which is conducted at lower temperatures and can, therefore, withstand higher impurity levels in the processing.

Decarbonize current steelmaking processes

The main route to decarbonize secondary steelmaking is to switch EAFs to clean electricity, which could involve a combination of grid decarbonization and onsite clean electricity generation, potentially paired with energy storage. This is key to enable full decarbonization with increasing recycled steel usage.

For primary steelmaking, DRI can be decarbonized by using clean hydrogen as the fuel and reductant source, eliminating both emissions sources and producing hydrogen-DRI (H_2-DRI). The two most advanced greenfield H_2-DRI-EAF projects are both in Sweden, only possible through a combination of cheap hydropower for producing green hydrogen, purchase commitments from buyers, government support, and strong collaborations across the steel value chain. Without any one of these factors, costs would likely be too high to compete with existing primary steelmaking. Both projects will also need high purity ore. Another steelmaker plans to build a greenfield H_2-DRI plant and melters to integrate it with existing BOFs, which should enable supply from lower grade ores and utilization of existing assets. Existing DRI facilities using natural gas could blend clean hydrogen to reduce emissions but would need equipment retrofits to be able to use 100% hydrogen for full decarbonization. For geographies where clean hydrogen is too costly to produce or procure, DRI using fossil fuels could be paired with carbon capture at additional cost but would require access to permanent CO_2 storage (CCS) or sufficient utilization opportunities (CCU).

The main option for BF-BOFs for deep decarbonization is carbon capture, which has the same costs and limitations as DRI-CCS/CCU. Moreover, this would require greenfield BF-BOFs using the best available technology, whereas retrofitting existing BF-BOFs with carbon capture is unlikely to reach more than 50% emissions reductions due to insufficient capture rates. It is possible that innovations in carbon capture technologies could deliver deeper reductions.

The use of certain biomass as a low-carbon fuel for DRI or BF processes could also provide a pathway for near-zero emissions (or even net-negative emissions if employing CCS/CCU). However, the competition for an already scarce resource with other industries for use as feedstock and the need to aggregate large quantities of biomass for a single ironmaking facility make this pathway unlikely to scale.

Develop new net-zero primary steel production processes

Given the limitations in every pathway to decarbonizing current primary steelmaking routes, innovation in completely new processes to replace ironmaking and/or steelmaking has the potential to create intrinsically net-zero processes with lower costs at scale.

One option is to use hydrogen as a reducing agent, like H_2-DRI, but to conduct the process at melt temperatures, enabling the use of lower grade iron ores. One company is aiming to do this with clean electricity as the energy source for smelting the iron in this hydrogen-electric approach. The process could produce iron or steel, depending on the addition of other inputs (e.g., scrap steel and/or refining elements).

Another option is to use clean electricity alone to directly reduce iron ore, eliminating both process heat and chemical process emissions and bypassing the need to first use electricity to produce clean hydrogen. One company is developing a process called molten oxide electrolysis, which performs the electrochemical reduction above the melt temperature, combining ironmaking and steelmaking in one, decarbonized step. Another company is developing a low-temperature electrochemical process, which produces high purity iron plates that can be processed in existing EAF infrastructure to produce high quality steel. Importantly, both technologies can use lower grades of iron ore, solving a major issue with H_2-DRI.

Combinations of these diverse technologies will have different costs (depending on energy costs, feedstock costs, and other geographical factors) and varying levels of residual emissions, but all should theoretically be able to reach close to net-zero emissions steelmaking.[10] How costs evolve over time and where supportive policies are put in place will significantly impact which technologies fully commercialize and scale over the next several years.

Policy Progress and Opportunities

While the last several years have shown exciting technological progress to decarbonize industry, many of these technologies are relatively early in their innovation lifecycle and need to undertake significant development and commercialization to reach wide deployment. Even for the already commercial technologies or those close to hitting the market, economic and non-cost barriers remain, preventing broader adoption. Smart policies that address the entire innovation cycle will be critical to accelerating technology advancement and market uptake in line with reaching our climate goals.

Due to the diversity of industrial subsectors and variety of technological solutions for reducing emissions, Breakthrough Energy largely follows a sector- and technology-agnostic policy framework that enables technologies to compete on a level playing field and leaves room for further innovation. Our policy priority areas generally fall into the following categories:

- Supporting **supply** of low-GHG industrial technologies and products through research, development, and demonstration (RD&D) investments and financial incentives;

[10] Mission Possible Partnership, Making Net-Zero Steel Possible (September 2022).

- Supporting public and private **demand** for low-GHG products to create markets and buyers to pull technologies forward and foster an environment for further investment;
- Employing **climate-aligned trade policies** and international cooperation to address carbon leakage, secure domestic industrial competitiveness, and influence global industrial emissions reductions; and
- Developing **foundational data infrastructure and analytical capabilities** that underpin the effective design and implementation of the above policies.

Thanks to the action of Congress in recent years, we've made significant strides in nearly every priority area and are poised to witness demonstrable progress enabled by key policies in the Energy Act of 2020, the Infrastructure Investment and Jobs Act (IIJA), the CHIPS and Science Act of 2022 (CHIPS), and the Inflation Reduction Act of 2022 (IRA). I will briefly outline examples of this progress and highlight where additional policy action will be needed.

Foundational Data and Analytics

Power sector decarbonization efforts have benefited from the ability to analyze different policies and decarbonization scenarios using multiple energy system models. Industrial sector modeling capabilities are far behind what is needed to be able to provide the same level of support for understanding the impacts of industrial policies. Industrial modeling resources can be expanded through (1) individual model improvements, (2) better coordination and collaboration among modelers, and (3) increased data availability and aligned technology assumptions for model inputs. DOE, the Energy Information Administration, and the National Labs comprise critical pieces of the industrial modeling ecosystem and can play leading roles in model and data improvement with additional resources and direction. These models should aim to better understand impacts of domestic policies, as well as internationally relevant policies around climate and trade.

To enable emissions intensity comparisons between industrial products and provide a basis for claiming cleaner production processes, there must be robust, transparent data infrastructure to support creation and use of environmental product declarations (EPDs), which are the bases for the procurement policies described below. EPDs are third party-verified documents created using international standards that report the embodied GHG emissions associated with producing a given product, based on life cycle assessment models. The Embodied Carbon in Construction Calculator (EC3) is a free database of construction material EPDs and a complementary impact calculator for building design and material procurement. The Environmental Protection Agency (EPA) received $250M in the IRA to provide technical assistance and funding for the production of EPDs by domestic manufacturers to enable their participation in public sector efforts to procure substantially cleaner materials.

Investments (Supply)

DOE is the primary federal agency responsible for industrial RD&D and requires adequate support for supply-side investments. Congress recognized the importance of industrial innovation in passing the Clean Industrial Technology Act of 2019—introduced by Senator Whitehouse and Ranking Member Capito—as part of the Energy Act of 2020. As a result of DOE reorganization and new funding streams from recent legislation, multiple offices across DOE address industrial decarbonization, namely the Industrial Efficiency and Decarbonization Office (IEDO) and Advanced Materials and Manufacturing Technologies Office (AMMTO) on the applied research and development (R&D) side, and the Office of Manufacturing Energy Supply Chains (MESC) and the Office of Clean Energy Demonstrations (OCED) on the demonstration and deployment side. To realize its full potential in supporting industrial innovation, DOE needs (1) increased funding across every office involved in industrial decarbonization through the annual appropriations process and other legislative vehicles and (2) durable high-level leadership to plan and execute DOE's industrial decarbonization strategy and ensure coordination between the relevant offices, such as through a new Assistant Secretary for Industrial Innovation.

To illustrate just the industrial R&D funding gap, it is informative to look at the President's FY2024 Budget Request for certain applied R&D technology offices. Solar and wind, two relatively mature renewable energy technologies that have already significantly come down the cost curve due to decades of public support, received budget requests of $379M and $385M, respectively. Meanwhile, IEDO, which is responsible for applied R&D for all industrial sector technologies largely at much earlier stages of maturity, received a similar budget request of $394M. It is difficult to imagine progress at the pace necessary for midcentury industrial decarbonization if IEDO has to split the same amount of resources as wind energy R&D across every industrial subsector. At minimum, a tripling of the current request to cover the three biggest emitters (chemicals, steel, and cement) would be a more reasonable request to meet the challenges IEDO is being asked to help solve. Given likely constraints of limited resources, one approach to rebalance R&D funding is through portfolio planning across DOE programs, which would allocate federal funding to different technologies based on a set of criteria (e.g., emissions reduction potential, complexity, maturity) rather than on historical funding levels.

For later stage support and investments, OCED received a historic $6.3B through IIJA and IRA for first- to early-of-a-kind commercial scale industrial decarbonization demonstration projects. DOE is currently reviewing applications for this Industrial Demonstrations Program and anticipates announcing awardee selections in early 2024. With up to 50% cost share and a maximum grant amount of $500M, this demonstration funding will be game changing in advancing commercial scale transformative projects that would have otherwise not moved forward or could have taken years or decades to break ground. While this level of funding for industrial decarbonization demonstrations is unprecedented, the summary of concept papers submitted reveals that it is still not enough. DOE received interest from projects requesting over $60B in federal funds, nearly ten times the total budget of the program. Furthermore, many breakthrough technologies were still too early in their development to qualify for the program. When these solutions are ready for their first commercial scale project in several years, it is imperative that DOE has funding to support them. Though not focused solely on industrial emissions, the Loan Programs Office (LPO) will also be critical to support nth-of-a-kind facilities for widescale deployment.

In addition to grants and loans, tax incentives can help bring down the costs of deployment-ready technologies to help them scale. DOE is supporting Treasury on implementation of the 48C advanced energy project credit, allocated at $10B through the IRA and expanded to include industrial emissions reductions. In previous iterations, 48C was also oversubscribed, indicating a large appetite from the private sector to take advantage of these credits. Relevant technology-specific tax credits are further discussed below.

On increased coordination, DOE has recently created a Joint Strategy Team (JST) to act as a coordinating body for their industrial decarbonization work, which we think is a step in the right direction. To maintain effectiveness, the JST will need durable structures with clear leadership and authority, as well as the resources for staff capacity. The Senate Appropriations Committee recognized this need for industrial emissions coordination, recommending a $3.5M line item for this express purpose, which Breakthrough Energy fully supports. In the future, DOE should consider placing this coordination function under the new Assistant Secretary for Industrial Innovation mentioned above.

Market Creation (Demand)

To create demand for lower-carbon industrial goods, it is necessary to (1) change current markets to favor existing, commercial technologies with lower emissions intensity and (2) shape future markets to provide offtake for emerging technologies to enable their commercialization. Breakthrough Energy considers four main areas that address one or both of these needs:

- **Public procurement** – direct government purchasing of industrial products;
- **Policies to facilitate future demand** – public policies that enable future public or private offtake;
- **Private procurement** – corporate commitments to purchase cleaner goods; and
- **Sectoral standards** – performance requirements or regulations on industrial goods or facilities.

Public Procurement

Governments purchase one third to one half of all cement and about one fifth of all steel, so public procurement policies that target green products—often called Buy Clean or green public procurement (GPP)—can create sizable markets for low-GHG industrial goods. Buy Clean policies are typically centered on procurement standards—emissions intensity limits for public purchase of industrial goods—and framed by data transparency through EPDs and public investments to support reducing the emissions intensity of domestic industry to meet increasingly stringent procurement standards.

The IRA included funding of over $5B for federal agency procurement of low-embodied carbon construction materials, with the majority of funding going to the General Services Administration (GSA) for federal buildings and the Federal Highway Administration (FHWA) for federally supported infrastructure. GSA recently announced plans to allocate their funding to over 150 projects across the country, and we anticipate FHWA to release funding to eligible states and local jurisdictions in the coming months. Both agencies will use an EPA interim determination to guide product emissions intensity limits that projects must meet to receive IRA funding. It is critical that these programs target materials with the lowest possible embodied carbon emissions and push the bounds of what suppliers can produce today.

While the IRA funding for clean procurement is unprecedented, for Buy Clean to reach its full potential, the federal government would need to adopt a Buy Clean standard that covers all agency purchases and increases stringency over time. It will also be important to augment federal clean procurement with state procurement efforts, which often cover different buildings and infrastructure. Several states (e.g., CA, CO, MN, NY, and OR) have already passed some form of Buy Clean standard, which could help create momentum for a federal standard in the future. Cities and states can also adopt embodied carbon requirements in building codes, which apply beyond publicly owned buildings to reach an even greater market.

GPP has also gained interest globally, with the UN Industrial Deep Decarbonization Initiative (IDDI) as the main convening platform to encourage more countries to commit to green procurement pledges, help foster dialogue between countries to aid in implementation, and facilitate harmonization of policies and standards across countries. The U.S. government should maintain close engagement with IDDI to ensure U.S. perspectives are represented in international commitments.

Policies for Future Demand

While Buy Clean creates new markets for commercially available lower emissions goods, most current public procurement policies are not designed to create tangible demand to enable commercialization and financing of near-zero breakthrough technologies for industrial decarbonization. Policymakers should explore new policy options to create this future demand and offtake, such as through advance market commitments or contracts for difference. DOE released a request for information on these types of demand-side policy measures for green cement/concrete and steel (among other products).

Private Procurement

In addition to public sector procurement, private sector procurement efforts can use the same EPD data infrastructure and policy framework as public programs. For example, Amazon, Google, Meta, and Microsoft penned an open letter inviting industry collaboration for how to accelerate the delivery of green concrete for data centers. In the near-term, these efforts help to address opportunities for already commercial technologies. On the other hand, the First Movers Coalition (FMC), an initiative created by the U.S. State Department and the World Economic Forum, is attempting to leverage the collective demand from private sector purchase commitments to create early markets for clean steel, cement/concrete, aluminum, chemicals, and other heavy industrial products. FMC commitments are forward-looking and aim to stimulate demand for technologies not yet in the market. For steel, FMC recently launched their Near-Zero Steel 2030 Challenge to enable bilateral offtake agreements. In partnership with FMC, RMI launched a Sustainable Steel Buyers Platform to foster long-term offtake agreements in the North American market.

Sectoral Standards

Beyond creating initial markets for cleaner industrial goods through public and private procurement, Breakthrough Energy envisions a clean products standard (CPS) as a longer-term policy priority for widescale deployment of industrial decarbonization technologies. Using the same data infrastructure as Buy Clean, a CPS would set a decreasing emissions intensity benchmark for each covered product (e.g., cement or steel), which all domestic manufacturers and importers would need to meet. A CPS would provide industry with a predictable glidepath to reach net-zero and could be designed to reward producers that outperform the benchmark to incentivize further innovation. Thus, a well-designed CPS could address both current and future markets for existing commercial products and emerging technologies, respectively.

Cross-Cutting Solutions Policies

As the collective understanding of the different roles for technology solutions in different sectors and subsectors becomes more sophisticated, there will be a need to employ technology-specific policies, especially in cases where there may be limited resources or trade-offs between adopting a technology in one sector versus another. In all cases, specific infrastructure needs will be critical to efficient and economic deployment, as well as robust community engagement on the risks and benefits of each technology. Here, I will focus on policies for a subset of the complementary cross-cutting technologies discussed above.

Electrification

The IRA includes several tax credits that can indirectly and directly help incentivize industrial electrification. In general, all the clean electricity production and investment tax credits should decrease overall costs of clean electricity that can be used by industry, or in the case of onsite generation, directly reduce costs of constructing or operating the clean energy asset. Potentially more relevant for industry is the 45X clean manufacturing production tax credit, which includes eligibility for battery modules. Treasury and the IRS are currently drafting rules for claiming these credits, which will determine whether TES will be eligible for 45X under the battery module definition. Ensuring that TES is able to claim 45X would help accelerate scaling of TES production and drastically reduce capital costs for industrial projects incorporating electrification through TES.

To more broadly enable industrial electrification, additional policy support will be needed to incentivize switching to electrification technologies like industrial heat pumps and TES, properly plan for increased industrial load alongside clean generation and transmission buildout, and address electricity market barriers to TES participation.

Research shows that to maximize the emissions reductions benefits delivered by the IRA, the United States must more than double the historical pace of electricity transmission expansion. However, accelerating the construction of high-voltage, interregional lines will require the reimagination of nearly a century of transmission policy. Breakthrough Energy supports efforts to thoughtfully streamline transmission siting and permitting in a way that facilitates deployment of critical clean infrastructure while maintaining our nation's bedrock environmental protections.

Hydrogen

Recent hydrogen policies, including the passage of the 45V hydrogen tax credit in the IRA and the regional clean hydrogen hubs program in IIJA, have focused on generating a cost-competitive supply of clean hydrogen. The 45V tax credit in particular has resulted in an important discourse on how to adequately balance two objectives embedded in the credit's innovative design: reducing emissions while enabling the scale up of emerging clean hydrogen technologies. Striking this balance will be difficult to do, but it is clear that additional guardrails are necessary to ensure grid-connected hydrogen projects demonstrably do not cause additional pollution, by procuring new clean power from the same region and as close in time to when the electrolyzer is running. It is possible to define and phase-in these guardrails so that they ensure truly clean hydrogen production will scale. This and other recent policies would help reduce operational costs of switching to clean hydrogen, however, these incentives do not ensure that supplies will be used in a targeted way to decarbonize industrial processes and other priority sectors. Given the additional capital cost barriers associated with switching to hydrogen-based processes, and non-cost barriers associated with encouraging industrial facilities to commit to making that switch, more policy support for demand-side uptake is needed.

DOE is currently developing its own demand-side support mechanism for utilizing hydrogen, which may provide up to $1B to close the cost premium gap for hydrogen used in industrial projects related to the selected hydrogen hubs. Their intent is to select one or more independent entities to execute this demand-side price support mechanism before the end of this year and collaborate with the entities in the first half of next year to undertake public and stakeholder feedback for the specific design of the mechanism. This demand-side support will be critical to ensuring not only sufficient demand for the expected supply from the hydrogen hubs, but also that the demand the program supports targets priority end-uses, like industrial decarbonization, that may have a lower willingness to pay and would otherwise not come to the table at this earlier stage of clean hydrogen production.

In addition to economically matching supply and demand, the enabling infrastructure needed to safely transport and store hydrogen to physically get the supply to the demand will be an important consideration for clean hydrogen applications. The choice of transport and storage technology can have a big impact on overall project costs and decarbonization potential, so policymakers must carefully think through how to efficiently and adequately incentivize and unlock developers' ability to build enabling infrastructure while avoiding over-subsidizing buildout that could lead to suboptimal climate outcomes.

Carbon Management

First introduced in 2008, 45Q provides a tax credit for CO_2 storage or usage. The IRA expanded and extended 45Q, including increasing the credit value for industrial applications to $85/tonne of CO_2 permanently stored and $60/tonne of CO_2 utilized. While this increase provides additional incentives for high purity, low capture cost applications (e.g., ethanol, natural gas processing), it is likely insufficient to fully cover the higher costs of lower purity sources (e.g., cement, steel), which will need additional cost reductions or other sources of revenue. The combination of 45Q with capex subsidies from other DOE programs, such as the $6.3B Industrial Demonstrations Program or the $2.5B Carbon Capture Demonstration Projects Program funded by IIJA (which requires two projects in the industrial sector) could provide enough incentives for a handful of low-purity applications to advance over the next several years.

To secure permanent emissions reductions, carbon capture will require transportation and distribution infrastructure for delivery to geologic sequestration facilities or utilization sites. Efficient buildout of shared infrastructure will help reduce individual project costs. The United States is not technically limited in its storage capacity, but buildout has been held back by the permitting times for storage wells. Storage needs the full suite of legal and regulatory policies, like long term liability transfer, indemnification funding, and state primacy, in order to scale safely. The magnitude of transportation infrastructure deployment will depend on the adoption of viable alternatives to carbon capture (e.g., electrification, clean hydrogen, new sector-specific production methods) and on the need for CO_2 as a feedstock into other processes (e.g., as an input with hydrogen to make e-fuels and e-chemicals).

Sector Specific Policies

Cement and Concrete

Infrastructure and building construction rely heavily on standards and specifications, which are often prescriptive and dictate the types of materials used in projects. The construction industry is also very risk averse and slow to change practices. These factors create barriers for adopting innovative technologies and materials, like low-carbon cement and concrete, that warrant specific attention.

Overcoming these barriers will require collaboration between industry stakeholders, policymakers, standardization organizations, and academia on a suite of complementary activities. Developing new methods for third party testing and validation of innovative technologies and materials that demonstrate their performance can decrease perceived risk from potential buyers and users. Alongside testing, some new materials may require updated industry standards and specifications to enable use in real projects. On top of updates to allow specific new materials, there should be a broader push to move the industry from prescriptive specifications that limit innovation to performance specifications, which allow any material to be used, as long as it meets performance characteristics that can be evaluated with robust testing and validation. State departments of transportation can play a leading role in the evolution to performance specifications, given the regional variation in the industry and their outsize influence in setting specification norms within their markets.

Successful demonstrations of new materials and technologies in low-risk construction projects or specific demonstration facilities (e.g., MnROAD pavement test track) can also help accelerate their adoption. Policy can help enable these demonstrations by providing funding to cover the extra costs associated with using the new technology or material, both the cost of the material itself and non-material costs, like additional testing, measurements, and labor costs to allow sufficient time that may be needed when learning to work with a new material. Fortunately, the IRA low-embodied carbon procurement funding at GSA and FHWA are designed to cover these exact costs and can help spur these types of demonstration projects across the country.

For broader innovative material adoption, education and awareness within the industry will be critical. The existing and new workforce will need training to break from traditional norms and learn how to regularly work with new technologies.

Iron and Steel

In the United States, two types of steelmaking dominate: integrated BF-BOFs and standalone EAFs, with a handful of DRI plants running on natural gas. U.S. emissions from iron and steel production have decreased over the last couple of decades, largely due to declining overall production and increased share (about two thirds) of production through EAF secondary steelmaking. The ratio of primary to secondary steelmaking is generally reversed in the rest of the world, which results in U.S. steel, on average, having one of the lowest emissions intensities among major steel producing countries. However, as previously discussed, there is not enough scrap supply to completely replace primary steelmaking capacity, and there are high end applications of steel (i.e., automobiles) that require higher quality steel that can currently only be provided through primary steelmaking. Thus, U.S. steel decarbonization cannot rely solely on secondary EAF methods and necessitates strategies for enabling primary steelmaking to transition to net-zero processes through further R&D, commercialization, and deployment policy support.

Congress authorized a steel RD&D program in CHIPS (originally the Steel Upgrading Partnerships and Emissions Reduction (SUPER) Act of 2021), which will require appropriations to execute. For H_2-DRI pathways (and any others involving the use of clean hydrogen), the 45V tax credit and hydrogen hubs program will help increase supply and decrease costs of clean hydrogen, lowering operational costs, while the DOE Industrial Demonstrations Program could provide a capex subsidy to further lower costs of this and other capital-intensive pathways. One study found that the current U.S. policy environment enables multiple configurations of brownfield and greenfield H_2-DRI-based steelmaking facilities to be financially viable. Despite these findings, of the nearly 30 announced H_2-DRI projects globally, none are in the United States. This warrants further attention, especially as DOE stands up its hydrogen demand program and reviews selections for the Industrial Demonstrations Program, alongside already announced hydrogen hub awardees.

For setting standards in demand-side policies, in the near term, it will be important to distinguish between primary and secondary steelmaking in determining product emissions intensity limits, so as to continue incentivizing decarbonization of primary steelmaking and the creation of primary steel EPDs, as well as secondary steelmaking. EPA's interim determination for the use of IRA funding proposes a bifurcated steel procurement standard to address this issue. As more data on individual steelmaking facilities becomes available (i.e., the percentage of scrap content used to manufacture a steel product), phasing in a sliding scale standard based on scrap percentage rather than production process—aligned with the international ResponsibleSteel standard, IDDI, and FMC—would be a more effective, technology-neutral option that would be more inclusive to innovative technologies.

Climate and Trade

The United States imports a large quantity of carbon-intensive manufactured goods, accounting for over one gigaton of embodied carbon, providing a further imperative for U.S. climate policy to address emissions produced abroad as well as at home. Additionally, for energy intensive trade exposed industries located in the U.S. to invest in decarbonization, trade policy must first address potential emissions leakage which would undermine industrial competitiveness and emissions goals. For a global system of climate-aligned trade to develop, research and consensus building on measurement and tracking of embodied carbon data is needed. It is encouraging to see Congress increasingly paying attention to this issue, with Members on both sides of the aisle working on proposals.

On enhancing embodied carbon data availability, Senators Coons and Cramer—with several Members of this Committee—introduced the PROVE IT Act of 2023, which would direct the DOE to study the emissions intensity of U.S. products relative to those produced in other countries.

While non-governmental organizations have published valuable estimates of America's "carbon advantage" and online tools for visualizing the embodied carbon in trade flows, a government-led study with access to real facility data from existing industry reporting will be necessary to underpin any kind of domestic policy addressing embodied emissions from imports, as well as to inform U.S. responses to policies adopted by other trading partners, like the EU Carbon Border Adjustment Mechanism (CBAM). With U.S. manufacturers increasingly developing EPDs to take advantage of domestic public and private clean procurement efforts, there is also an opportunity to maximize EPD data interoperability with the data infrastructure informing climate-aligned trade policies.

Building off of the ideas in the PROVE IT Act, Senators are also developing U.S. border adjustment or import fee policies to address carbon leakage and competitiveness. Last Congress, Senator Whitehouse introduced the Clean Competition Act, which would create a carbon border adjustment mechanism that charges energy intensive imports, while simultaneously incentivizing the domestic reduction of industrial emissions. Many U.S. industries are already much cleaner than their foreign counterparts, and ensuring domestic industries continue to decarbonize will help American manufacturers maintain their competitive advantage under increasing international climate-aligned trade regimes. Last month, Senator Cassidy—with co-sponsorship from Senator Graham—introduced the Foreign Pollution Fee Act, which would impose a fee on imports of select energy and industrial goods, depending on the relative emission intensity of their production compared to average U.S. production. Importantly, the bill would leverage these fees to create international partnerships to address industrial emissions, using climate competition to promote collaboration. Both of these proposals provide key pieces of a U.S. climate-aligned trade policy that could ultimately build toward global collaboration to clean up industry and trade by leveling the playing field for domestic and foreign producers alike, creating a race to the top. Breakthrough Energy supports further bipartisan discussions to develop a climate and trade policy that ensures domestic industries can maximize their clean investments to bolster competitiveness and puts a spotlight on manufacturing emissions abroad to incentivize industrial decarbonization around the world.

As the United States contemplates a domestic border adjustment policy, it will also be important to begin working with other countries on a path forward toward international cooperation on climate and trade, such as through a climate alliance or carbon club. Because countries are adopting different domestic policies to tackle climate change and some, like the EU, are already in the process of implementing a CBAM tied to their internal carbon pricing system, it is unrealistic to expect all countries to agree on a single, harmonized climate policy framework. Rather, the goal should be to facilitate policy interoperability, primarily through agreement on using product emissions intensity as a key metric and cooperation on data measurement, reporting, and transparency.

There are several international fora where cooperation on climate and trade is being considered. The United States and the EU continue to negotiate a Global Arrangement on Sustainable Steel and Aluminum (GASSA), which would address non-market excess capacity and carbon intensity of these goods and allow tariff-free trade between the two jurisdictions. The G7 is another group of key countries, which could help nucleate an international alliance on climate and trade. Notably, the G7 climate, energy, and environment ministers included several points on climate and trade cooperation in their official communique this year, including an emphasis on emissions intensity as a key factor for implementing policy instruments.

Conclusion

Without further intervention, the industrial sector will likely become the highest-emitting U.S. sector within the next decade. Addressing industrial emissions will require accelerated innovation, enabled by supportive policies throughout the R&D, demonstration, commercialization, and deployment stages of a technology's lifecycle, including supply-side investments, demand-side market creation, climate-aligned trade policies, and supporting data and analytical infrastructure. Decarbonizing industry will not only contribute to achieving net-zero emissions, but it will also bolster American competitiveness, retain and create good-paying manufacturing jobs, and provide positive health impacts to workers and surrounding communities.

The world is on the brink of a clean industrial revolution, and America is poised to take the lead. I urge the Members of this Committee and Congress to not let this opportunity pass us by.