DEEP DIVE

Decarbonizing Heavy Industry

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Executive summary

- **What is heavy industry?** Heavy industry is a loosely defined term that generally applies to capital- and energy-intensive industries involving complex production processes, such as cement, steel, aluminum, and petrochemicals. Heavy industry accounts for around one-third of global greenhouse gas emissions but has historically been seen as a hard-to-decarbonize sector. Reasons for this include high heat requirements, decentralized CO_2 emissions, low profit margins, high capital costs, increased operating costs, and long infrastructure lifetimes.
- **How could efforts to decarbonize heavy industry reduce greenhouse gases?** Technical interventions to reduce heavy industry emissions include switching to lower-carbon production processes (e.g., replacing fossil fuel inputs with hydrogen or direct electrification); carbon capture, utilization, and storage (capturing process emissions and storing them or converting them to value-added products); development of alternative materials (e.g., substitutions for cement and fossil-based plastic); and increasing material usage efficiency and adopting a circular economy approach.
- **Theory of change for decarbonizing heavy industry:** We think that supporting nonprofits advocating for governments to accelerate heavy industry decarbonization is a powerful lever for impact. We also think that supporting nonprofits working in regions with high heavy industry production is a promising strategy. Our impression is that some of these regions have less developed civil society ecosystems, and so individual nonprofits are likely to have a greater marginal impact. Specific philanthropic sub-strategies vary depending on the industry sub-sector, but we think the most promising sub-strategies increase research, development, and demonstration (RD&D) funding; low-carbon purchase commitments; or heavy industry policy support or regulation. We think that this would result in reduced production costs for low-carbon products compared to the counterfactual, and therefore more producers opting for low-carbon production.
- **What is the cost-effectiveness of decarbonizing heavy industry?** We developed a highly subjective, rough-guess cost-effectiveness analysis (CEA) to estimate the cost-effectiveness of efforts to decarbonize heavy industry (in terms of dollars per metric ton of CO_2-equivalent reduced/avoided). As a proxy for these efforts, we estimated the effect that an advocacy campaign might have on increasing the cement emissions reduction targets of the US Federal Buy Clean Initiative, as well as such policies' subsequent impact on cement emissions reductions worldwide. Overall, we think that efforts to decarbonize heavy industry could plausibly be within the range of cost-effectiveness we would consider for a top recommendation. Though we have low confidence in this CEA to estimate the cost-effectiveness of this specific philanthropic effort, we generally view it as a positive input to our overall assessment of decarbonizing heavy industry.
- **Is there room for more funding?** It is our general impression that philanthropic support for decarbonizing heavy industry has increased but continues to remain underfunded, at an estimated 2.6% of total foundation climate funding.[1] Within heavy industry, certain subsectors and

[1] Figure 3: "Known Foundation Support to Regions, Sectors, and Strategies, Annual Average, 2018-2022, USD Millions." Desanlis et al., "Funding Trends 2023: Climate Change Mitigation Philanthropy," ClimateWorks, 2023.

geographies are also comparatively underfunded, such as cement and chemical decarbonization and regions outside of the US and EU. Overall, we think this sector likely has significant room for more funding.

- **Are there major co-benefits or adverse effects?** We think decarbonizing heavy industry could significantly reduce local pollution. It could have unclear employment effects as global industries grow, shrink, and change due to decarbonization.
- **Key uncertainties and open questions:** In general, we are uncertain about the cost-effectiveness of R&D efforts, the efficacy of government funding support, geographic focus, general equilibrium effects, and heavy industry regulatory code.
- **Bottom line / next steps:** We have identified heavy industry as a priority impact area and therefore plan to consider organizations working on industrial decarbonization for both Top Nonprofits as well as grants from the Giving Green Fund. Heavy industry is a substantial contributor to emissions, and we think there are relatively high-leverage opportunities to affect government decision-making and increase the geographical diversity of actors working on heavy-industry decarbonization. We may expand the scope of our investigation in the future by focusing on specific high-potential decarbonization subsectors and generally plan to devote more research capacity to exploring organizations and initiatives that are based in countries where substantial future heavy industry production will be located.

What is heavy industry?

Heavy industry is a loosely defined term that generally applies to capital- and energy-intensive industries that involve complex production processes.[2] Cement, steel, aluminum, and petrochemicals are examples of heavy industry products with especially large carbon footprints.[3] Compared to other emissions sources, heavy industry may also be relatively difficult to decarbonize or require specific solutions. For example, some industrial processes have high heat requirements or relatively decentralized CO_2 emissions. Economic factors such as low profit margins, high capital costs, and long infrastructure lifetimes can further discourage industries from switching to lower-carbon production.[4] There are also challenges with co-dependencies and constraints across sectors that share resources or techniques for decarbonization strategies. Examples include the development and scaling of green hydrogen, clean heat, and CO_2 transportation and storage.

How could efforts to decarbonize heavy industry reduce greenhouse gases?

Heavy industry accounts for around one-third of global greenhouse gas (GHG) emissions.[5] There are a variety of interventions needed to reduce emissions from heavy industry, including lower-carbon production processes; carbon capture, utilization, and storage (CCUS); development of alternative materials; and increasing material usage efficiency.[6]

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[2] "Heavy industry refers to an industry that produces large industrial products, which requires large and heavy machinery and facilities and involves complex production processes.... It is very capital intensive and requires significant investment in heavy equipment, massive buildings, large machine tools, and extensive infrastructure." Corporate Finance Institute, "Heavy Industry, n.d."; "Energy-intensive industries (EIIs) produce basic materials, such as steel, petrochemicals, aluminum, cement, and fertilizers, that are responsible for around 22 percent of global CO_2 emissions (Bataille 2019)." Åhman, "Unlocking the 'Hard to Abate" Sectors," WRI, n.d.; "More than one-third of emissions come from heavy transport such as trucks and planes and the heat-intensive manufacture of materials such as steel and cement." Lovins, "Decarbonizing Our Toughest Sectors — Profitably," MIT Sloan, 2021.

[3] "You can think of this in four product categories: cement, steel, plastic, and fertilizer. Just making those materials is responsible for two-thirds of all the greenhouse gas emissions from the entire industrial sector." "Rebecca Dell on decarbonizing heavy industry," Volts Podcast, 2022.

[4] "Steel, cement, and chemicals are the top three emitting industries and are among the most difficult to decarbonize, owing to technical factors like the need for very high heat and process emissions of carbon dioxide, and economic factors including low profit margins, capital intensity, long asset life, and trade exposure." Gross, "The Challenge of Decarbonizing Heavy Industry," Brookings, 2021; "In addition, these sectors are highly capital-intensive, have long investment and asset replacement cycles, and have a high cost of carbon mitigation." Kashyap & Purkayastha, "Policies and Enabling Environment to Drive Private Investments for Industrial Decarbonization in India," Climate Policy Initiative, 2023.

[5] "Globally, the picture is even starker: there has been a 21% increase in emissions from industry since 2005. Of the 49 gigatons of worldwide GHG emissions in 2021, more than 14 gigatons (29%) are direct emissions from industry....What's more, domestically and globally, we project that industrial emissions are likely to increase in the coming decades." King et al., "Expanding the Industrial Decarbonization Toolkit," Rhodium Group, 2024.

[6] These strategies are loosely based on reviewing several strategic frameworks for decarbonizing heavy industry, including: Gross, Brookings, 2021; U.S. Department of Energy, "DOE Industrial Decarbonization Roadmap," n.d.; Fischedick et al., "Industry," *Climate Change 2014*, IPCC, 2014; "Bucket number one is *material efficiency*. We can just use less of this material in order to make the products and deliver the services that we want.... Bucket number two, *carbon capture and storage*. You keep doing pretty much what you're doing now, but you figure out a way to collect all the carbon dioxide and put it underground.... Bucket three is *hydrogen*.... Bucket number four is *direct electrification*....Bucket number five is *bioenergy*." Volts Podcast, 2022.

Technical interventions

Switch to lower-carbon production processes

Energy and process emissions can be reduced with a variety of strategies. For example, producers can replace carbon-intensive energy inputs (e.g., metallurgical coal) with lower-carbon inputs such as hydrogen or bioenergy, or with direct electrification from lower-carbon electricity.[7] Process emissions result from the manufacturing process itself (e.g., calcination reaction for cement) and could potentially be reduced with different raw materials or chemical processes.[8] For example, a research group at Ecole Polytechnique Fédérale de Lausanne is leading a project to develop limestone calcined clay cement, a blend of two materials that has demonstrated a 40% reduction of CO_2 emissions.[9]

Implement carbon capture, utilization, and storage

Carbon capture, utilization, and storage (CCUS) involves capturing carbon emissions generated during the manufacturing process and either storing or making use of them. We view CCUS (also loosely referred to as "CCS" or "carbon capture") as an important potential pathway to reduce emissions. The International Energy Agency (IEA) notes that achieving net-zero emissions for industrial applications without CCUS could be significantly more expensive.[10] However, deployment is in its early stages, can be costly, and is less viable for industries that have many emissions points in their processes. CCUS also increases facilities' energy and water use, which can make operations more expensive.[11] CCUS may currently be financially nonviable for industries that lack highly concentrated sources of emissions, such as those with facilities that have many decentralized emission points (e.g., small process heaters in a steel plant).[12] According to the Global CCS Institute, there were 41 CCS projects in operation in 2023, including commercially available CCUS technology used by industrial facilities.[13]

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[7] "Lower the carbon footprint of energy sources and feedstocks by using lower-carbon fossil energy and introducing low-fossil carbon sources such as nuclear heat and electricity, clean electricity, clean hydrogen, or biofuels." DOE, n.d.

[8] The calcination reaction accounts for approximately 50% of total emissions in cement production. Fischedick et al., IPCC, 2014; "People do have ideas for alternative raw materials or alternative cement chemistries that might be able to address this process emissions problem without CCS." Volts Podcast, 2022.

[9] Limestone calcined clay cement can reduce the clinker content by half, and CO_2 emissions by "up to 40%." LC3, "About LC3."

[10] "In the [Limited CO_2 Storage scenario variant], the limited availability of CO_2 storage would result in a doubling of the marginal CO_2 abatement cost by 2060 relative to the CTS where CCUS is widely available." IEA, "Transforming Industry through CCUS." 2019.

[11] "Capturing the CO_2 can decrease power and industrial plants' efficiencies and increase their water use, and the additional costs posed by these and other factors can ultimately render a CCS project financially nonviable." Gonzales et al., "Carbon Capture and Storage 101," RFF, 2022.

[12] "The rest of [steel facility emissions] is all these small sources — little process heaters here and there — that are distributed by the dozens all over a facility that's the size of a town. Thinking about how you would collect all of the carbon dioxide from all those distributed sources and do that cost effectively is really hard." Volts Podcast, 2022.

[13] Table: "2023 Facilities List, Operational." Global CCS Institute, "The Global Status of CCS," 2023; "For pre-combustion capture technologies, there are commercially available technologies used by industrial facilities." Gonzales et al., RFF, 2022.

Develop alternative materials

For certain industrial pathways, there are opportunities to develop alternative materials that may reduce the carbon intensity of the process (e.g., substituting supplementary cementitious materials for clinker in cement) or eliminate the need for fossil-based feedstocks (e.g., bioplastics).[14] Limitations to this intervention type include: (a) viable alternatives do not necessarily exist for all pathways or use cases, (b) the full life-cycle emissions of producing these alternative materials must be considered, (c) alternative materials are not always cost-competitive with conventional products, and (d) constraints on feedstock availability may inhibit scalability to meet demand.

Increase material usage efficiency

Producers reduce material requirements during the manufacturing process, and/or consumers use less of the final product. We think this is a highly certain way to reduce emissions. Additionally, it does not require technological advances and, if feasible, should often be highly cost-effective (since producers or consumers simply use less than they otherwise would have). However, we think material usage efficiency will usually only result in marginal gains because we think industries and consumers are generally only willing or able to reduce consumption by marginal amounts. We view it as relatively unlikely that the sector would reduce consumption by 50% absent any broader technological advances, and think realistic reductions would be more like 10–20%; however, we acknowledge that this might vary by context and industrial pathway. For example, in one modeling study, a net-zero concrete pathway for Japan was 80% based on supply-side interventions and just 20% on demand-side reductions.[15] Another study found that in the UK, cement emissions could be reduced by 50% through material efficiency techniques.[16]

If material usage efficiency gains are minimal, this might further encourage inaction in cases where industrial products are a relatively small portion of a product's cost.[17] Purchase decisions may also be relatively removed from consumers (e.g., an apartment buyer does not make steel procurement decisions), which might make increasing consumer-based material usage efficiency more difficult.[18] It is

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[14] "It has been found that substituting SCMs for cement reduces carbon emissions in concrete without compromising strength and durability." Althoey et al., "Advancements in low-carbon concrete as a construction material for the sustainable built environment," *Developments in the Built Environment* 16, 2023.

[15] "Our analysis shows that a series of mitigation efforts on the supply side can reduce 2050 CO_2 emissions by up to 80% from baseline levels and that the remaining 20% mitigation gap can be fully bridged by the efficient use of cement and concrete in the built environment." Watari et al., "Efficient use of cement and concrete to reduce reliance on supply-side technologies for net-zero emissions," *Nature Communications* 13, 2022.

[16] "We produce a final estimate of the total reduction in emissions achievable from material efficiency: 51.3%." Shanks et al., "How much cement can we do without? Lessons from cement material flows in the UK," *Resources, Conservation, and Recycling* 141, 2019.

[17] For example, if a $30,000 car requires one ton of steel and steel costs $1,500 per ton, 10% material usage efficiency savings are $150, equivalent to 0.5% of the total car price. Calculation: (.1*1500)/30000 = 0.005. Sources: "<1% for a small car containing 1 tonne of steel and priced between 20,000 to 30,000 USD)" Agora Industry, "Global Steel at a Crossroads," 2021; "May [2022 futures] contracts for US Midwest Domestic Hot-Rolled Coil Steel (CRU) are currently trading between $1400 and $1500 per ton." Sumler, "US Steel Confident on Rising Steel Costs; Prices Persisting," Nasdaq, 2022.

[18] Additional example on chemicals: "[Chemical companies] have also largely escaped public pressure to change their practices, since they operate in the background, removed from the consumer-facing companies that they supply." Fray, "Chemicals: core to a net zero future," *Financial Times*, November 16, 2022.

possible that material usage efficiency could result in substantial GHG emissions reductions for some heavy industry products. For example, overhauling building codes might allow the construction sector to consume substantially less steel or cement per building constructed. We have not investigated material usage efficiency closely, and may look into industry-specific opportunities in the future.

Other circular economy strategies, such as material recirculation and circular business models, could also decrease the amount of new material that must be produced. We think that circular economy strategies could significantly reduce industrial emissions but should be combined with other decarbonization strategies, as there is a cap on how much reduction is practically feasible. For example, one Material Economics study estimated that material usage efficiency strategies could reduce the GHG emissions of four key industrial materials (cement, steel, aluminum, and plastic) by 10.5% by 2050, and adding material recirculation and circular business models could increase this reduction to 56%.[19]

Philanthropic efforts to decarbonize heavy industry

To determine where we should focus our analysis, we broadly considered a number of "sub-strategies": ways in which philanthropic efforts might be targeted at direct decarbonization efforts, consumer influence, corporate advocacy, and government advocacy.

We evaluate each sub-strategy's scale, feasibility, and funding need (see **Table 1**). See Giving Green's Research Process for more information on these metrics and our research process.

Given the potential for political and geographic variance of tractability and relevance, we have contextualized these sub-strategies in countries/regions that we think might be especially strategic based on the potential for outsized impact as well as the availability of funding opportunities (see **Table 2**).[20]

[19] Calculation: material usage mitigation = 56/530 = 10.5%, circularity mitigation = (178+56+62)/530 = 56%; From figure: "A more circular economy can cut emissions from heavy industry by 56% by 2050." Material Economics, "The Circular Economy: a Powerful Force for Climate Mitigation," 2018.

[20] This is informed, in part, by Giving Green's work on LMICs.

Table 1: Sub-strategies to decarbonize heavy industry

Strategy	Scale	Feasibility	Funding Need	Notes
Use philanthropic funds to directly fund heavy industry research, development and demonstration (RD&D)	Medium	Medium	Medium	Additional RD&D funding is necessary to develop and scale new decarbonization technologies in certain industries. However, it's our general impression that (a) some funding already exists (e.g., $6 billion in the Inflation Reduction Act for demonstration facilities[21]) and (b) not all decarbonization efforts require technological advances. Most importantly, we think directly funding research has medium scale since we think that nonprofits can mobilize more resources by leveraging government funds than directly fund RD&D with philanthropic dollars. See "Advocate for government funding for RD&D" row in this table.
Advocate to consumers to reduce demand for heavy industry products (e.g., steel) and/or products comprised of heavy industry products (e.g., cars)	Low	Low	High	Advocacy activities could include media campaigns, demonstrations, etc. We think this area is generally less funded because of its low scale and feasibility. In particular, heavy industry is often more of a business-to-business (B2B) sector rather than directly consumer-facing.
Advocate to consumers to demand low-carbon products	High	Low	High	Advocacy activities could include media campaigns, demonstrations, etc. We think this area is generally less funded because of its low feasibility. For the reasons mentioned above as potential limitations to consumer material efficiency, we don't believe consumer demand generally represents a tractable pathway to decarbonizing heavy industry.
Support low-carbon coalitions	High	Medium	Medium	Low-carbon coalitions (which could include nonprofits, academics, governments, or companies) would ostensibly focus on reducing the carbon intensity of heavy industry products, so we think this generally represents a high-scale opportunity since it could result in substantial GHG reductions. We think there is already some focus on coalition-building, so we generally classify this strategy as having a medium funding need. However, we think it may be more neglected with respect to certain pathways and geographies. We think that coalitions, especially those composed of or including private companies, may suffer from having to satisfy all members and thus have a bias towards low-ambition efforts. However, it is also our impression that coalitions without representation from the private sector may have less influence.

[21] "The U.S. Department of Energy (DOE) today announced up to $6 billion for 33 projects across more than 20 states to decarbonize energy-intensive industries....The projects will create and maintain tens of thousands of high-quality jobs and help accelerate the commercial-scale demonstration of emerging industrial decarbonization technologies." DOE, March 25, 2024.

Table 1: Sub-strategies to decarbonize heavy industry (cont.)

Strategy	Scale	Feasibility	Funding Need	Notes
Advocate to corporations to make low-carbon procurement commitments	High	Medium	Medium	We think this could be a high-scale approach, especially in the context of certain industrial products, e.g., aluminum, for which certain sectors, and a few large companies within these sectors, constitute the bulk of demand. We think corporations may generally be reluctant to make low-carbon purchase commitments; most corporations are primarily dedicated to profit maximization and would only make low-carbon purchase commitments in cases where either (a) it already represents the status quo or (b) could increase profit. For additional commentary, see the "Advocacy influences corporations to commit to low-carbon purchase standards" subsection in our "Theory of change" section.
Advocate to governments to make low-carbon procurement commitments	High	Medium	High	We think this is feasible because (a) we think philanthropic dollars can be directed to activities that influence government policymaking and (b) there is substantial and growing precedent for low-carbon procurement policies. Our impression is that national governments have been more likely to commit to RD&D funding than public procurement commitments. However, there is growing momentum for green or sustainable public procurement on local, national, and international levels in the US, EU, and China. For additional commentary, see the "Advocacy influences government to pass low-carbon procurement policies" subsection in our "Theory of change" section.
Advocate for government funding for RD&D	Medium	High	High	We think that the scale of this strategy is medium because there are certain pathways for which we think demand-pull mechanisms will be more powerful levers that could unlock the requisite RD&D within the private sector. The feasibility of this strategy varies by country, but given past successes, such as provisions within US climate legislation such as the Infrastructure Investment and Jobs Act and the Inflation Reduction Act (IRA), Japan's Green Innovation Fund, and the EU's Net Zero Industry Act, we think continued advocacy is highly feasible.[22]

[22] NEDO, "Overview of the Green Innovation Projects," 2021; European Commission, "Net Zero Industry Act," 2023; "The BIL and IRA provided unprecedented public sector funding and unlocked historic levels of private sector investment for developing and deploying critical emissions reduction technology to decarbonize heavy industry." Kielty, "Paving the Way to Industrial Decarbonization," NRDC, 2024.

Table 1: Sub-strategies to decarbonize heavy industry (cont.)

Strategy	Scale	Feasibility	Funding Need	Notes
Support corporations to use existing government funding	Low	High	Medium	Philanthropic efforts could fund organizations to either provide direct technical assistance that helps corporations access funding or advocate for governments to more explicitly direct existing funds to heavy industry. Since funding is already generally allocated towards these efforts, we consider this relatively feasible. For additional commentary, see the "Advocacy leads to more government transition funding and/or more corporations using existing funding" subsection in our "Theory of change" section. Because there is already a financial incentive for corporations to use this funding, we think this sub-strategy has only a medium funding need.
Advocate for government to establish a supportive regulatory framework	High	Medium	High	As with philanthropic efforts to influence government procurement policies, we think government advocacy can increase the likelihood of a supportive regulatory framework for decarbonizing heavy industry. The EU's Net Zero Industry Act is an example.[23] There is also evidence to show that regulatory measures have historically been some of the most impactful policies to reduce national emissions.[24] However, it is our impression that regulatory policy is (a) relatively more complicated to influence and (b) more likely to face political opposition than procurement policies. For additional commentary, see the "Advocacy leads to governments establishing a supportive regulatory framework" subsection in our "Theory of change" section.

[23] "The Net-Zero Industry Act (NZIA) creates a regulatory framework to boost the competitiveness of EU industry and technologies crucial for decarbonisation." European Commission, "The Net-Zero Industry Act: Accelerating the transition to climate neutrality," n.d.

[24] "In the industry sector, pricing plays a prominent role. It is most effective individually in developed economies (43%) and shows the most synergy with other policies in developing economies (50%). However, subsidies can be effective complements in both contexts." Stechemesser et al., "Climate policies that achieved major emission reductions: Global evidence from two decades," *Science* 385, no. 6711, 2024.

Table 1: Sub-strategies to decarbonize heavy industry (cont.)

Strategy	Scale	Feasibility	Funding Need	Notes
Strengthen civil society presence in regions with high heavy industry production	High	Medium	High	Our impression is that civil society engagement in industrial decarbonization has significant room for growth in certain regions where heavy industry manufacturing is concentrated. We think there is value in supporting civil society in these countries to provide technical assistance to corporations and governments, hold them accountable, and advocate for ambitious policies. This could be especially high-scale in avoiding carbon lock-in in countries like India, which are quickly building new heavy industry infrastructure.[25] We think that the funding need in this area is high, as funding could be absorbed both by established nonprofits expanding their international work or by local nonprofits in relevant countries and because it will require significant capital to grow nonprofit ecosystems in these countries. We think that coalition-building activities could be a promising way to amplify the leverage of nonprofits in regions where representation is relatively sparse. We rate feasibility as 'medium' as it could be difficult for nonprofits to gain traction and the trust of governments and corporations at the early stages.
International collaboration, inclusive of LMICs	High	Medium	Medium	International collaboration is important for industrial decarbonization as this sector is highly traded and serves global markets. High-income countries are well-positioned to remove the financial and technological barriers associated with industrial decarbonization for low- and middle-income countries (LMICs). Bilateral partnerships with LMICs and high-emitting countries could involve mechanisms to provide climate finance, technology transfer, the development of shared low-carbon standards, and the sharing of knowledge and experience. Multilateral partnerships foster a joint approach to innovation, standard setting, and trade, which can result in cheaper and faster decarbonization. Partnerships act as a complement to measures such as the Carbon Border Adjustment Mechanism (CBAM) in a 'carrot and stick' approach. We think the feasibility is medium as it takes considerable effort to form such partnerships, along with existing good diplomatic relations.[26] However, existing partnerships, such as the EU-India Clean Energy and Climate Partnership and the Industrial Deep Decarbonization Initiative, demonstrate that they are feasible.[27] We think this sub-strategy has a medium funding need as there are already various international and well-funded organizations that work to foster such collaboration, such as UNIDO, the Clean Energy Ministerial, and UNFCCC.

[25] "In India, the industrial sector is the largest and fastest-growing energy end-use sector and is expected to be the single largest source of CO2 emissions by 2040." Kashyap & Purkayastha, Climate Policy Initiative, 2023.

[26] "It is generally accepted that new partnerships should not be seen as low-effort measures and will not happen without significant effort." Future Matters, "8 EU Policy Priorities for Global Decarbonization," 2024.

[27] EU-India Clean Energy and Climate Partnership; Industrial Deep Decarbonization Initiative

Table 2: Sub-strategies contextualized in specific countries/regions

Context	Highly relevant sub-strategies	Scope of impact
Asia	• Advocate for government funding for RD&D • Advocate to governments to make low-carbon procurement commitments • Advocate for government to establish a supportive regulatory framework • Advocate to corporations to make low-carbon procurement commitments • Strengthen civil society presence in regions with high heavy industry production	Asia is by far the largest manufacturing region, producing ~73% of both the world's steel and concrete.[28] We think that incentivizing producers in Asia to shift towards low-carbon production, either through corporate or government advocacy, is likely to be a direct and high-scale strategy to reduce global emissions from heavy industry. In some countries, the political and economic environment, as well as the ease of cross-border philanthropic flows, can make advocacy more challenging. Overall, we think that there is sufficient political will to decrease industrial emissions in some important countries for philanthropic efforts to be feasible, as evidenced by India's green steel plan and Indonesia's low-carbon cement roadmap.
Australia[29]	• Advocate for government to establish a supportive regulatory framework • Advocate for government funding for RD&D	Due to Australia's unique comparative advantages—abundant solar and wind resources, abundant raw materials, and a strong export market—it may be able to decarbonize a significant portion of heavy industry at a lower cost than almost any other country would. This approach would affect Australia's domestic heavy industry and also a significant portion of global heavy industry emissions through Australia's exports. Some economists estimate that Australia could decarbonize an estimated 7% of global emissions. For more information, see Giving Green's report on High-Impact Climate Giving In Australia.
EU	• Advocate for government to establish a supportive regulatory framework • Advocate to governments to make low-carbon procurement commitments • Advocate for government funding for RD&D • Advocate to corporations to make low-carbon procurement commitments	We think that the EU is an important region for both technology and policy innovation and that EU policy is likely to continue to affect global emissions. For example, the EU's Carbon Border Adjustment Mechanism (CBAM) incentivizes its importers to reduce the embedded emissions of products and also incentivizes foreign policymakers to enact their own carbon prices. EU policymakers have a history of collaboration with nonprofits, and we think that EU policy is especially open to nonprofit advocacy.[30] Major industrial sectors are already included in the EU's Emissions Trading Scheme and Innovation Fund, and we think that further policy wins are highly feasible in this policy cycle.

[28] "Production and consumption of cement are largely concentrated in Asia, accounting for 73% of the output globally and a consumption of 81%." Arc Group, "The Cement Industry in Asia," 2022; Calculation: Figure: Crude steel production, 2022: 54 + 6.6 + 4.7 + 8.1 = 73.4% World Steel Association, "World Steel in Figures," 2023.

[29] Although we do not include organizations working in Australia in our list of global top nonprofits or Giving Green grantees, we were funded separately to conduct an assessment of high-impact giving opportunities in Australia. Through this work, we identified decarbonizing industry exports as the most promising philanthropic strategy to address climate change from within Australia and identified a list of top Australian nonprofits working on this impact area.

[30] Referring to environmental NGOs: "In a typical year, the EU supports between 25 and 30 organisations." European Parliament, n.d. "Targeted advocacy by NGOs such as the European Climate Foundation was also a key ingredient to driving policy change" Kreienkamp et al., "Explaining transformative change in EU climate policy," 2022.

Table 2: Sub-strategies contextualized in specific countries/regions (cont.)

Context	Highly relevant sub-strategies	Scope of impact
US	• Advocate for government funding for RD&D • Advocate for government to establish a supportive regulatory framework • Advocate to governments to make low-carbon procurement commitments • Advocate to corporations to make low-carbon procurement commitments • Strengthen civil society presence in regions with high heavy industry production	We think that US civil society groups can have an outsized impact through a combination of (a) public and private investment for domestic expansion and decarbonization of industrial production and (b) trade policy that favors cleaner industrial material imports. Our impression is this is feasible given the implications on domestic competitiveness, momentum behind existing efforts to decarbonize US industries (e.g., Industrial Demonstration Program, Buy Clean policies), and bipartisan interest in import tariffs based on carbon intensity in response to the EU's CBAM.[31] We also think that it could be highly impactful for US groups to engage in efforts to support, exchange knowledge with, and collaborate with civil society groups working in regions of high heavy industry emissions, especially where there has been historically less philanthropic engagement.

Based on the considerations above, we believe the most promising strategies target governments and focus on advocacy for regulation and/or public funding. We also believe that increasing the participation of actors in LMICs and/or countries where heavy industry is concentrated is a neglected and important impact lever. In addition, we think that for certain industrial products and contexts, engaging directly with private-sector producers or consumers could be highly effective. We assess these specific strategies within the broader theory of change in the following section.

Theory of change of decarbonizing heavy industry

We think it is difficult to summarize a broad theory of change for this sector since industries can vary substantially in terms of GHG emissions, technology, economic model, and regulatory environment. However, our impression is that heavy industry can generally be decarbonized if there is (a) adequate demand for low-carbon products, (b) a supportive regulatory framework, and (c) transition assistance that facilitates a switch to low-carbon production. Examples of transition assistance include R&D funding, demonstration hub funding, tax credits, or direct commercialization co-funding (additional detail below). We developed a high-level theory of change to illustrate how this might play out in practice (**Figure 1**).

[31] "Proposals for policies at the intersection of climate and trade are becoming increasingly popular around the world and in the U.S." Gangotra et al., "4 US Congress Bills Related to Carbon Border Adjustments in 2023," WRI, 2023.

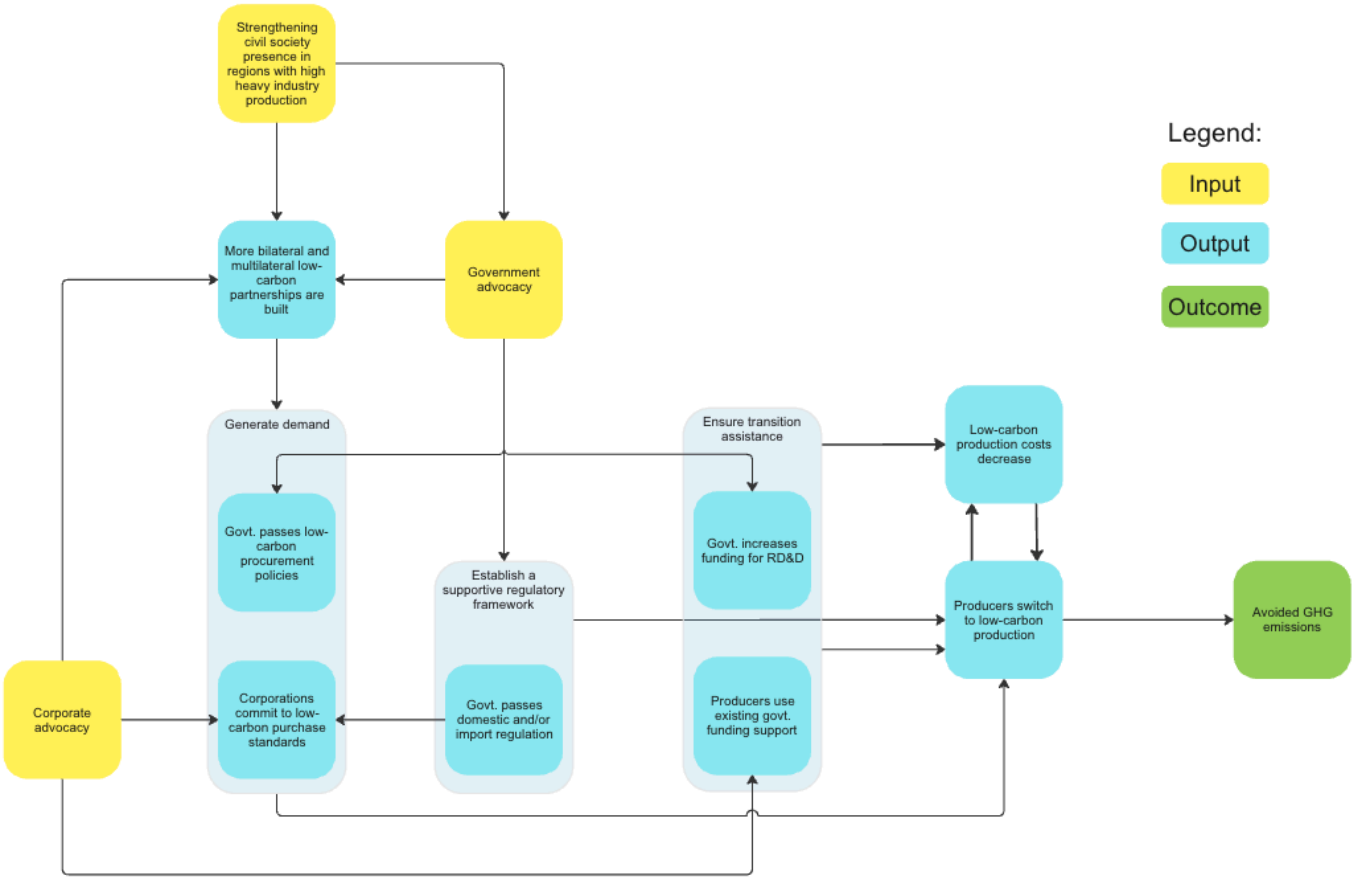

Figure 1: High-level theory of change for decarbonizing heavy industry

We include "low-carbon production costs decrease" as an output because we believe it is an important pathway for some industries. Additionally, we think it is useful to illustrate the virtuous cycle that can exist between producers switching to low-carbon production and low-carbon production costs declining. However, we think the degree to which cost decreases matter varies substantially by industry. For example, research organization Agora believes low-carbon steel costs are currently palatable for automakers and their consumers.[32]

Though this theory of change describes global decarbonization efforts, we purposefully do not specify a country-specific or global pathway since we think this varies too much by industry and strategy. As an example, consider aluminum production. In 2021, China produced an estimated 57% of the world's primary aluminum, so it could make sense to focus decarbonization efforts directly on Chinese governments and corporations.[33] Alternatively, efforts might advance fastest by encouraging the

[32] Agora, a research organization, estimates low-carbon steel increases car prices by around 1%. "The additional premium for green steel (~200 to 300 USD per tonne of steel) can be passed on to end consumers, only marginally increasing the price of the car (<1% for a small car containing 1 tonne of steel and priced between 20,000 to 30,000 USD)." Agora Industry, 2021.
[33] Calculation: 38837/67092=0.578. See interactive graphic: "Primary Aluminium Production," 2021 annual. International Aluminum, "Statistics," 2024.

Canadian government to provide additional transition funding in the spirit of their $120 million CAD investment in zero-carbon smelting technology.[34] Or it could make sense to apply pressure to the global automotive industry, which accounts for 29% of primary aluminum consumption.[35] We think each industry's decarbonization strategy should consider its unique challenges and opportunities to inform its geographical pathway to global decarbonization.

We also recognize that the civil society ecosystem advocating for industrial decarbonization is less developed in some of the countries with the greatest manufacturing potential of green industry products. We think that increasing the strength and number of civil society groups is an important way to accelerate the green industrial transition.

Examining the assumptions behind the theory of change for decarbonizing industry

Below, we discuss and evaluate the main assumptions related to the theory of change for decarbonizing heavy industry. We rank whether we have **low**, **medium**, or **high** certainty about each assumption.[36] Our assessment is based on both primary and secondary evidence, as well as our general impression of the plausibility of the assumption. Importantly, a number of the stages of this theory of change may not be amenable to easy measurement or quantification, are not supported by a robust evidence base, or are expected to occur in the future but have not happened yet. Additionally, we think the importance of each assumption varies on an industry-by-industry basis.

1. Advocacy influences governments to pass low-carbon procurement policies (**high certainty**)

Advocating for government procurement product standards could directly lower carbon emissions for government-purchased products and might subsequently shift general production to lower-carbon outputs. Levels of government procurement vary by country and industry, but governments are generally major buyers. For example, government procurement was 27%, 13%, and 11% of steel demand in 2019 for India, Japan, and South Korea, respectively.[37] In 2019, EU public procurement accounted for 31% of

[34] "When fully developed and implemented, it will eliminate direct greenhouse gas emissions from the smelting process....Canada and Quebec are each investing $60 million (CAD)." Elysis, May 10, 2018.
[35] Rough estimate based on 29% of aluminum being used by "Automotive and transportation" sector in 2022. We guess that 80% of this sector's use is attributable to the automotive sector, but have not looked into this. "This bar graph shows the major global uses of aluminum in 2022. The largest use was for automotive and transportation (29%)...." Government of Canada, "Aluminum facts," 2023.
[36] We describe our certainty as low/medium/high to increase readability and avoid false precision. Since these terms can be interpreted differently, we use rough heuristics to define them as percentage likelihoods the assumption is, on average, correct. Low = 0-70%, medium = 70-90%, high = 90-100%.
[37] "Government-funded construction and infrastructure projects accounted for around 27%, 13%, and 11% of total steel demand in India, Japan, and South Korea in 2019, respectively." Hasanbeigi and Bhadbhade, "Green public Procurement of Steel in India, Japan, and South Korea." Global Efficiency Intelligence, 2023.

cement demand and 11% of steel demand.[38] The US government also claims to be the largest purchaser in the world, and a major infrastructure funder.[39] As part of the IRA, $5.5 billion was allocated to various federal agencies for low-carbon procurement of industrial materials for transport and buildings.[40]

We have high certainty that this is viable in different political contexts. This is because there is a substantial and growing precedent for low-carbon procurement policies, as evidenced by the Industrial Deep Decarbonization Initiative's Green Public Procurement Pledge, which was signed in 2023 by seven key governments (Austria, Canada, Germany, Japan, the UAE, the UK, and the US). This pledge requires signatories to either adopt timebound procurement commitments for low-emissions steel, cement, or concrete and/or to set emissions reduction thresholds to achieve net zero emissions in public buildings and/or infrastructure.[41]

Our general impression is that there is more traction for green public procurement in high-income countries, as LMICs, understandably, may not prioritize spending additional funding to procure lower-carbon heavy industry products. Public procurement accounts for only around 12% of GDP in OECD countries but up to 30% in lower-income countries.[42] This difference may start to shrink with the implementation of trade policy, such as the EU's Carbon Border Adjustment Mechanism, which incentivizes the EU's trade partners, including LMICs, to more aggressively regulate industrial emissions.

Public procurement policies are also becoming increasingly commonplace at more local levels. For example, the US state of New Jersey recently passed legislation establishing state and local purchasing requirements for low-carbon concrete, and several states, including Washington, Oregon, Minnesota, and Colorado, have passed general Buy Clean legislation.[43] The Biden Administration's Buy Clean Task Force has prioritized low-carbon federal government procurement of steel, concrete, asphalt, and flat glass.[44]

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[38] Public sector procurement "accounts for approximately 31%" of the cement market, but "public procurement's share in the steel market is notably smaller, capturing only about 11% of apparent usage in the EU." Brussels School of Governance, "Public Procurement of Steel and Cement for construction," n.d., p.9.

[39] "The Federal Government is the largest direct purchaser in the world and a major infrastructure funder." The White House, September 15, 2022.

[40] "Critically, it also provides roughly $5.5 billion in funding allocations across multiple federal agencies to help procure low carbon industrial materials for transportation and building infrastructure projects." Stashwick, "Climate Bill Will Invest Big in Cleaning Up Heavy Industry," NRDC, 2022.

[41] "The governments of Canada, Germany, the United Kingdom and the United States, member countries of the Industrial Deep Decarbonization Initiative (IDDI), pledged to adopt timebound commitments to procure low-emission steel, cement and concrete, and/or to set emissions reduction thresholds for whole project life cycle assessments to achieve net zero emissions in public buildings and/or built infrastructure." "I am pleased to see governments like Canada, Germany, the UK, the US, and Austria, Japan and the UAE lead the way." UNIDO, December 5, 2023.

[42] "Public procurement wields enormous purchasing power, accounting for an average of 12 percent of gross domestic product (GDP) in OECD countries, and up to 30 percent of GDP in many developing countries." UN Environment Programme, "Sustainable Public Procurement," n.d.

[43] New Jersey: "New Jersey Senate Bill 3091…establishes…State and local purchasing requirements." New Jersey Senate Bill 3091; Other states: "Buy Clean got its start in the states and work continues in earnest to adopt Buy Clean policies in statehouses across the nation." BlueGreen Alliance, "Buy Clean in the States," n.d.

[44] Buy Clean Task Force: "President's Biden [*sic*] charged his Administration through his December 2021 Federal Sustainability Plan and Executive Order 14057 to launch a Buy Clean Task Force" charged with "identifying construction materials and products with the highest embodied carbon concerns—such as steel, cement/concrete, asphalt and flat glass—to prioritize for lower

2. Advocacy influences corporations to commit to low-carbon purchase standards (**medium certainty**)

There are reasons why corporations may be reluctant to make low-carbon purchase commitments. Most corporations are primarily dedicated to profit maximization, and are unlikely to make low-carbon purchase commitments unless it either (a) already represents the status quo or (b) could increase profit.

As illustrated in our theory of change, low-carbon purchases could become the de facto status quo due to government regulation or low-carbon products generally becoming the market standard. In these cases, advocacy efforts to push corporations to make low-carbon purchase commitments would not have any additional impact.

In some cases, we believe low-carbon purchase commitments could increase profits for corporations. This could be due to increased revenue (e.g., by increased purchases from environmentally-conscious customers) or decreased costs (e.g., by increasing access to environmentally-conscious lenders). For both of these cases, philanthropic dollars could fund direct or indirect efforts to make low-carbon purchases relatively profitable. As with government commitments, corporate advocacy efforts could include activism (e.g., consumer awareness media campaigns), shareholder advocacy, and insider advocacy efforts (e.g., direct engagement with corporate executives).

We think corporate advocacy could either cause increased corporate awareness of an already existing profit opportunity or shift actual economics such that low-carbon commitments become the most profitable path forward. However, we have low certainty in both of these strategies. In general, we believe corporations are relatively aware of existing profit-making opportunities—and as mentioned previously, the economics of many heavy industry products can make it difficult for low-carbon switches to be profitable without transition support.[45] We also think advocacy efforts to shift profitability might be low-promise since the general public is relatively removed from heavy industry products (e.g., private citizens purchase vehicles rather than aluminum to manufacture vehicles).[46]

We think some corporate commitments are likely to be meaningful, and there is some precedent for heavy industry corporations engaging in commitments. For example, around 60 industrial corporations have signed on to reduce GHG emissions by 50% over 10 years via the Biden administration's Better

embodied carbon consideration in Federal procurement and federally-funded projects." Office of the Federal Chief Sustainability Officer, "Federal Buy Clean Initiative," n.d.

[45] "Steel, cement, and chemicals are the top three emitting industries and are among the most difficult to decarbonize, owing to…economic factors including low profit margins, capital intensity, long asset life, and trade exposure." Gross, Brookings, 2021.

[46] Additional example on chemicals: "[Chemicals] have also largely escaped public pressure to change their practices, since they operate in the background, removed from the consumer-facing companies that they supply." Fray, *FT*, 2022.

Climate Challenge.[47] Furthermore, the First Movers Coalition (90+ members in 2024) and SteelZero (40+ members in 2024) are both initiatives to advocate for corporate low-carbon purchase commitments. The Sustainable Steel Buyers Platform is an initiative to connect these corporations to low-carbon steel suppliers who launched their one-million-metric-ton-per-year low-carbon steel purchase commitment in 2024.[48] This gives us some confidence this is a potentially feasible pathway to change. However, we are uncertain about whether corporate advocacy caused these commitments, as well as whether these commitments represent a faster decarbonization shift than would have otherwise occurred.

3. Supporting the growth of the civil society ecosystem in regions with high heavy industry production leads to increased global action on heavy industry decarbonization (**high certainty**)

While the production of heavy industry products happens globally, there are a few regions and countries where the bulk of production is concentrated. For example, China accounted for 60% of global cement production in 2020.[49] China and India are the top two steel-producing countries, accounting for 59% of production in 2023.[50] Therefore, we believe that efforts to influence policy and markets in Asia, in particular, could have a high direct impact and result in positive ripple effects globally. However, despite the region's dominance in terms of heavy industry output, our impression is that the local civil society ecosystem engaged in the decarbonization of heavy industry has been underfunded and has significant room for growth.

We think philanthropic dollars enabling advocacy by civil society might be especially effective at influencing policy and markets in these regions, including through direct advocacy or by developing analyses that are accessible and relevant to policymakers.[51] For example, some stakeholders believe that funding non-profit advocacy work to change government procurement standards is the most feasible way to generate enough demand for low-carbon products such that heavy industry shifts its overall

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[47]"Across the industrial sector, 60 companies have joined the Better Climate Challenge where they've committed to reducing portfolio-wide greenhouse gas (GHG) emissions by at least 50% by 2030." The White House, October 20,2022; "Through the Better Climate Challenge, organizations can partner with DOE to reduce portfolio-wide GHG emissions (scope 1 & 2) by at least 50% within 10 years." Participants listed include Ford Motor Company, General Motors, Mitsubishi Electric Automotive America, Nissan North America, and Toyota Motor North America. US Department of Energy, "Better Climate Challenge".

[48] "On Tuesday, during Climate Week NYC, members of the Sustainable Steel Buyers Platform launched a competitive bidding process asking steelmakers to deliver a total of 1 million metric tons per year of 'near-zero emissions' steel to North America by 2028. The idea is for steel companies to submit proposals to the group of buyers, then negotiate a price premium and other details in a final offtake agreement — a crucial contract that's needed to get projects moving." Gallucci, "Big steel buyers make a request for 1M tons of green steel," Canary Media, 2024.

[49] "The top five cement producing countries (China, India, Vietnam, United States and Indonesia) account for approximately 68.2% of global cement production in 2020, with China alone accounting for over 60% of the total global production (4.2 billion metric tons in 2021, according to National Bureau of Statistics of China)." Tkachenko et al., "Global database of cement production assets and upstream suppliers," *Scientific Data* 10, no. 696, 2023.

[50] "China produced 67.4 Mt in December 2023, down 14.9% on [*sic*] December 2022. India produced 12.1 Mt, up 9.5%." "World crude steel production for the 71 countries reporting to the World Steel Association (worldsteel) was 135.7 million tonnes (Mt) in December 2023"; calculation: (67.4+12.1)/135.7=58.6% World Steel Association, "December 2023 Crude Steel Production," 2024.

[51] "Insider advocates use techniques including: One-on-one lobbying and meetings with decision-makers,...Direct policy support through the creation or editing of policy proposals and draft legislation, Policy research and dissemination focused on providing an intellectual basis and talking points to support the creation of policy." Giving Green, "Insider policy Advocacy Overview," 2020.

production to lower-carbon outputs without needing harder-line regulation.[52] We expect that organizations recommended by Giving Green would be capable of contextualizing strategies to reflect the relevant regional and political opportunities.

4. Advocacy leads to governments establishing a supportive regulatory framework (domestic and/or international) (**medium certainty**)

As with philanthropic efforts to influence government procurement policies, we think government advocacy can increase the likelihood of a supportive regulatory framework for decarbonizing heavy industry. However, we only have medium certainty in this assumption, since it is our impression that regulatory policy is (a) relatively more complicated to influence and (b) is more likely to face political opposition than procurement policies.

We think regulatory influence is generally more complicated because impactful regulation is more likely to occur at the federal or international level; for example, the EU's Emissions Trading Scheme (ETS) was found to reduce carbon emissions in the studied EU states by 10% from 2005–2012 without significant impacts on firm-level profits and employment.[53] Philanthropic funding could be used to solidify legal precedent for the US Environmental Protection Agency (EPA) Clean Air Act to reduce heavy industry pollution under the Clean Air Act, which can then be used nationwide.[54] Solidifying precedent for state-level regulation may either be less applicable or inapplicable to other geographies.

Local regulation may also cause leakage, whereby stricter decarbonization regulation in one area, without protection against high carbon intensity imports, causes heavy industry to relocate to a different location and continue emitting GHGs. Regulations, such as the EU's Carbon Border Adjustment Mechanism (CBAM), are intended to prevent such leakage and have shown promise so far. Modeling studies have found that it is likely to reduce carbon leakage, and it has also influenced countries like China to accelerate the inclusion of certain heavy industry sectors in its carbon market.[55] Empirical evidence will still be needed to confirm the CBAM's effect after it begins implementation in 2026.

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[52] Anonymized conversation, September 1, 2022.

[53] "Installation-level data from national Polluting Emissions Registries in France, Netherlands, Norway and the United Kingdom point to a reduction in carbon emissions in the order of −10% between 2005 and 2012" "Meanwhile, firm-level data on the 31 ETS-regulated countries shows that the EU ETS had no significant impact on profits and employment" Dechezleprêtre et al., "The joint impact of the European Union emissions trading system on carbon emissions and economic performance," *Journal of Environmental Economics and Management* 118, 2023.

[54] For example: "Chevron Phillips Chemical Company LP has agreed to make upgrades and perform compliance measures estimated to cost $118 million to resolve allegations that it violated the Clean Air Act....Once fully implemented, the pollution controls are estimated to reduce emissions of climate-change-causing greenhouse gases, including carbon dioxide, methane and ethane, by over 75,000 tons per year." US Department of Justice, March 9, 2022.

[55] "We show that CBAM is effective in reducing carbon leakage." Bellora & Fontagné, "EU in search of a Carbon Border Adjustment Mechanism," *Energy Economics* 123, 2023; "We found the carbon border adjustment mechanism reduces carbon leakage by 19%." Sun et al., "The carbon border adjustment mechanism is inefficient in addressing carbon leakage and results in unfair welfare losses," *Fundamental Research* 4, no.3, 2023; "China will expand its national carbon trading market to include the steel, aluminum, and cement industries at the end of the year." "Chinese authorities hope lower emissions will help soften the blow from a new carbon tariff, known as CBAM, to be imposed by the European Union from 2026"; Bloomberg News, "China to Add Steel, Aluminum and Cement to Carbon Market in 2024," September 8, 2024.

Regulatory influence can also face political opposition, which can reduce the role and effectiveness of philanthropic funding. Whereas procurement policies reward heavy industry for decarbonizing, it is our impression that regulation is more often perceived to be penalizing and/or market-distorting and can face substantial opposition. For example, some evidence suggests the private sector may financially support climate policy obstruction, including via trade organizations.[56] At an international level, punitive regulation such as the US's 2018 25% tariff on imported steel may be opposed by other countries and result in protracted trade arbitration or countervailing tariffs.[57]

5. Advocacy leads to more government transition funding and/or more corporations using existing funding (**high certainty**)

As noted above in our assessment of corporations committing to low-carbon purchase standards, we think corporations are primarily dedicated to profit maximization and would only decarbonize in cases where either (a) it already represents the status quo, (b) could increase profit, or (c) would positively impact reputation. We think substantial government transition assistance is an important strategy to increase the likelihood of both of these scenarios. For example, an analysis by the Mission Possible Partnership estimates that transitioning the global steel asset base to net-zero-compliant technologies will require an additional $8 billion to $11 billion annually—orders of magnt the annual philanthropic support for decarbonizing all of industry.[58] Using philanthropic funding to leverage relatively higher amounts of government funding could be a promising strategy to ensure transition assistance.

One of our main reasons for having high certainty in this assumption is that government transition funding already exists. For example, as part of the IRA, the US Department of Energy allocated up to $6 billion to accelerate commercial-scale demonstration facilities for emerging industrial decarbonization technologies.[59] Indirect incentives such as the 45Q tax credit also provide direct payment or tax credit to CCUS implementers on a per-ton basis.[60] Across all IRA provisions, corporations are eligible for around

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[56] "A lurking climate denial apparatus, funded with anonymous money, shifted into high gear. Outside spending in 2010's congressional races increased by more than $200 million over the previous midterm elections…" Mueller and Whitehouse, *The Scheme: How the Right Wing Used Dark Money to Capture the Supreme Court*, 2022; "The U.S. Chamber of Commerce has been fighting climate-change legislation and is now opposing federal efforts to regulate CO_2 emissions." Goho, "The U.S. Chamber: A Record of Obstruction on Climate Action," Yale Environment 360, 2010.

[57] "Trump imposed 25% tariffs on imported steel and 10% on imported aluminum from most countries in 2018, arguing that these protections were necessary for U.S. national security to maintain healthy domestic production." Lawder, "U.S. court upholds Trump's national security tariffs on steel imports," Reuters, February 4, 2021.

[58] Calculation: 9,500,000,000 [estimate of additional annual steel transition investment requirement] / 55,000,000 [annual philanthropic support for industry] / =0.006. Steel transition: "According to an analysis by the Mission Possible Partnership, transitioning the global steel asset base to net-zero-compliant technologies will require an additional $8 billion to $11 billion in investment annually." Kooijmans, "The Sustainable STEEL Principles: Forging a New Paradigm," RMI, 2022; Industry philanthropy: Figure 3, "Known Foundation Support to Regions, Sectors, and Strategies, Annual Average, 2018-2022, USD Millions. Industry: $60M." Desanlis et al., Climateworks, 2023.

[59] "The U.S. Department of Energy (DOE) today announced up to $6 billion for 33 projects across more than 20 states to decarbonize energy-intensive industries…. The projects will create and maintain tens of thousands of high-quality jobs and help accelerate the commercial-scale demonstration of emerging industrial decarbonization technologies" DOE, 2024.

[60] "The major [IRA] changes to 45Q are: Raising the credit values to $85 and $180 for both point source and direct air capture respectively; Providing a direct pay and transferability option for developers who claim the credit." Bright, "The Inflation Reduction Act creates a whole new market for carbon capture," CATF, 2022.

$216 billion in tax credits.[61] We think this provides strong suggestive evidence that there may be additional government transition funding assistance in the longer term. The presence of similar programs in other countries, such as the UK and EU, makes us think that advocacy for similar mechanisms in more countries could be feasible, albeit at a smaller scale.[62] For example, India's green steel policy and Australia's net-zero industry plan, both currently in development, may include transition funding.[63] We also think that there may be bipartisan support for US trade policy, especially in anticipation of EU's carbon border adjustment mechanism implementation.[64]

A complementary strategy to advocating for new funding is helping corporations take advantage of existing funding. Philanthropic efforts could fund organizations that either provide direct technical assistance that helps corporations access funding or advocate for governments to more explicitly direct existing funds to heavy industry. Since funding is already generally allocated towards these efforts, we view this as relatively feasible.

What is the cost-effectiveness of decarbonizing heavy industry?

As a rough plausibility check, we developed a cost-effectiveness analysis (CEA) to estimate the cost-effectiveness of efforts to decarbonize heavy industry (in terms of dollars per metric ton of CO_2-equivalent reduced/avoided). As a proxy for these efforts, we estimated the effect that an advocacy campaign might have on increasing the cement emissions reduction targets of US Buy Clean policies (e.g., moving from a "low" reduction target of 10% to a "high" reduction target of 30%), as well as these policies' subsequent impact on cement emissions reductions worldwide. Focusing this CEA on one industry means this CEA is likely not generalizable to decarbonizing heavy industry's overall cost-effectiveness. Instead, it serves as a high-level sense-check of whether decarbonization efforts might be highly cost-effective. We chose to develop a more specific CEA because we think a CEA of decarbonizing heavy industry overall would include too many highly subjective guess parameters for us to have any confidence in its results.

Despite the narrow focus of this CEA, it still includes highly subjective guess parameters and should not be taken literally. In particular, we guessed the campaign cost, the campaign's impact on the US government's decisions to increase emissions reduction targets, the effect of target changes on US emissions reductions, and the effect of Buy Clean policies on global emissions reductions. Overall, we

[61] "The majority of the $394 billion in energy and climate funding is in the form of tax credits. Corporations are the biggest recipient, with an estimated $216 billion worth of tax credits." McKinsey, "The Inflation Reduction Act: Here's what's in it," 2022.
[62] "Over £190 million will be made available to help industry in the transition to net zero, reducing emissions as they switch to cleaner, cheaper energy." UK Department for Energy Security and Net Zero, January 22, 2024; "The Commission is today opening the Innovation Fund's 2023 call for proposals with a record budget of €4 billion to support the deployment of innovative decarbonisation technologies" EU Commission, November 22, 2023.
[63] "The Steel Ministry has begun work towards formulating a comprehensive green steel policy." Law, "India starts work on green steel policy, The Hindu Business Line, April 2, 2024; Australian Government Department of Industry, Science and Resources, "Net zero sector plans for industry, resources and the built environment," 2024.
[64] "CBAM proposals in the United States are gaining bipartisan momentum, especially after the European Union passed a CBAM in October 2023, which will be gradually implemented over the next ten years. Passing a U.S. CBAM would ensure that domestic remain globally competitive as these policies are rolled out in other countries." Joint Economic Committee, "What is a Carbon Border Adjustment Mechanism (CBAM) and what are some legislative proposals to make one? 2024.

think decarbonizing heavy industry efforts could plausibly be within the range of cost-effectiveness we would consider for a top recommendation.[65] This is primarily due to heavy industry's substantial GHG emissions, the government's large role as a heavy industry consumer, and the potential effect that government emissions targets might have on reducing the carbon intensity of global heavy industry products. Though we have low confidence in this CEA to estimate the cost-effectiveness of this specific philanthropic effort, we generally view it as a positive input to our overall assessment of decarbonizing heavy industry.[66] See below for a high-level explanation and the model itself for additional notes and citations.

- **Costs:** We guessed total campaign costs to be around $15 million, based on five organizations with $1 million annual budgets working on this campaign for three years.
- **Avoided GHG:** We estimated direct avoided GHG based on Buy Clean policies targets, as well as indirect global effects due to these efforts. For Buy Clean policies, we primarily relied on a 2021 Global Efficiency Intelligence report estimating the concrete consumption and emissions of US local, state, and federal governments. We modeled the campaigns' effects as increasing the likelihood that Buy Clean policies increase the ambition of their targets.[67] For global emissions, we used the IEA's 2030 net-zero goals for concrete and compared them to present-day tCO_2e-intensity to guess that GHG emissions could drop by 22% per unit of concrete.
- **Effectiveness:** For both Buy Clean policies and global emissions, we guessed that the campaign increased the likelihood of emissions reductions by 5%. For US local and state governments, we guessed that the campaign only targeted 50% of overall possible emissions. For all effects, we assumed reductions would have otherwise occurred at a later date, such that the campaign's marginal impact is limited to a five-year period in our best guess scenario.
- **Results:** Our best guess is that this campaign avoids one tCO_2e for around $3 (range: $0.63-$65). Within our best guess, we additionally estimated cost-effectiveness if the campaign does not impact non-US government emissions. We also developed a Guesstimate version of this CEA, which allowed us to assign ranges of values and probability distributions for certain inputs, and found similar results.

[65] As a heuristic, we consider something to plausibly be within the range of cost-effectiveness we would consider for a top recommendation if its estimated cost-effectiveness is within an order of magnitude of $1/$tCO_2e$ (i.e., less than $10/$tCO_2e$).
[66] We describe our confidence as low/medium/high to increase readability and avoid false precision. Since these terms can be interpreted differently, we use rough heuristics to define them as percentage likelihoods our takeaway (i.e., [not] plausibly within the range of cost-effectiveness we would consider recommending) is correct. Low = 0-70%, medium = 70-90%, high = 90-100%.
[67] Figure ES-1 Global Efficiency Intelligence, 2021

Is there room for more funding?

Support for decarbonizing heavy industry has increased, but some areas remain neglected

Heavy industry has experienced an uptick in philanthropic interest in recent years. However, it remains an underfunded sector of the climate landscape. The Climate Policy Initiative reported that in 2023, industry made up just $9 billion, or 0.7% of the $1.27 trillion spent on climate finance.[68] For foundation funding, industry represented just $60 million per year, or 2.6%, of the $2.3 billion per year average total climate funding from 2018-2022.[69] There has been a 24% increase from 2021 to 2022. We think that this sharp growth is necessary, and there remains room for more funding, considering heavy industry represents 30% of global emissions.[70]

Furthermore, we suspect that philanthropic spending may neglect certain geographies. For example, we expect India to continue to ramp up its manufacturing and energy demand, but ClimateWorks Foundation estimates that in 2022, foundations spent only $4 million per year addressing India's industry emissions, compared to $35 million per year in the US and Canada.[71] Efforts to decarbonize industry in China—the world's largest producer of steel and cement—received $16 million in 2022.[72] Given that China produces more than 50% of the world's steel and cement, we think that this is a potentially neglected area.[73] This might be because nonprofit activities in China are highly restricted, leading to an expected lower impact.

Major funders of decarbonizing heavy industry

Foundations that have provided major funding for decarbonizing heavy industry include the Bezos Earth Fund, ClimateWorks Foundation, and various foundations in the Global Fertilizer Challenge. The Bezos Earth Fund spent at least $22.5 million on decarbonizing heavy industry between 2020 and 2024.[74] In

[68] Figure ES1: "Landscape of Climate Finance in 2021/2022." Climate Policy Initiative, Global Landscape of Climate Finance, 2023.
[69] Figure 3: "Known Foundation Support to Regions, Sectors, and Strategies, Annual Average, 2018-2022, USD Millions." Desanlis et al., ClimateWorks, 2023.
[70] Increasing funding for industrial decarbonization: "The next two sectors with the fastest funding growth between 2021 and 2022 were transportation and industry (+24% each)." Desanlis et al., Climateworks, 2023; 30% of global emissions: Figure: "Global greenhouse gas emissions by sector." (Industry 5.2% + Energy use in industry 24.2% = 29.4%) Ritchie, "Sector by sector: where do global greenhouse gas emissions come from?" Our World in Data, 2020.
[71] Table 1: "Known Foundation Funding by Regions, Sectors, and Strategies, 2022, USD Millions." Desanlis et al., ClimateWorks, 2023. Note on spending: ClimateWorks' tracking of worldwide philanthropic giving is based on "funding data from foundations with major climate programs, publicly available data on official development assistance flows, and, more recently, data on donations from individuals to climate-relevant causes" (p.22). It seems likely that this report undercounts philanthropic giving from small individual donors, a group that is harder to track.
[72] Table 1: "Known Foundation Funding by Regions, Sectors, and Strategies, 2022, USD Millions." Desanlis et al., ClimateWorks, 2023.
[73] "China is the world's largest producer of steel and cement, accounting for more than 50% of both." Gross, Brookings, 2021.
[74] Bezos Earth Fund spent $12.5M on creating markets for climate-safe cement and steel in 2020, $9M on accelerating industrial decarbonization in 2021, and $1 million jump-startingi the global clean hydrogen market in 2024. Some of its other grants include a partial focus on decarbonizing heavy industry (e.g., using low-carbon building materials), but we did not include these in our calculations. Bezos Earth Fund 2020, 2021, 2024.

2023, ClimateWorks Foundation granted about $9.3 million to efforts focused on decarbonizing heavy industry and is also building the Industry Hub, a funder coalition for industrial decarbonization.[75] The Global Fertilizer Challenge includes various foundations and investors who have committed $21.5 million total to improve how fertilizer is made and used.[76] The European Climate Foundation also has an industry program, but we are unsure how much funding they provide.[77]

Are there major co-benefits or adverse effects?

In general, we think a major benefit could include pollution reduction in areas with heavy industry manufacturing or processing facilities (e.g., aluminum smelters). Absent new pollution laws or increased enforcement of existing laws, decarbonizing heavy industry generally results in reduced pollution if lower-carbon production is less polluting than high-carbon production.[78]

Decarbonizing heavy industry may also have unclear effects on global employment. For example, if Buy Clean policies expand US heavy industry, this could result in increased US employment (e.g., by allowing a US aluminum smelter to remain open). However, if US import tariffs cause high-carbon production facilities in a foreign country to close, this could negatively impact foreign country employment. We have not looked into whether, overall, we expect decarbonizing heavy industry to increase or decrease global employment.

Key uncertainties and open questions

In general, we are uncertain about the cost-effectiveness of R&D efforts, the efficacy of government funding support, geographic focus, general equilibrium effects, and heavy industry code.

- **R&D cost-effectiveness:** Decarbonizing certain industrial sectors will require substantial R&D to determine alternative processes or materials.[79] We are uncertain whether this research will successfully produce viable alternatives at reasonable costs, if these alternatives can feasibly scale, and how long this R&D might take. We also think there may be some instances in which investing in heavy industry R&D will result in avoided GHG emissions. However, investing those funds in carbon removal R&D or implementation to compensate for these emissions may have

[75] ClimateWorks spending: "Total: $9.3 million." ClimateWorks, "Grant Database," 2023; "Funding to support the Industry Hub to accelerate industrial decarbonization." Quadrature Climate Foundation, "Active grants," n.d.

[76] "As the United States and other partners announced funding commitments to the Global Fertilizer Challenge (GFC), a group of leading philanthropies and investors, including Climateworks Foundation, the Grantham Foundation, S2G Ventures, the Walton Family Foundation, and the William and Flora Hewlett Foundation, among others, announced a commitment of $21.5 million to improve how fertilizer is made and used." ClimateWorks, November 12, 2022.

[77] European Climate Foundation, "Europe's industrial transformation," n.d.

[78] "Adding carbon capture could reduce CO_2 emissions and soot (particulate matter) by close to 90% while Sulfur dioxide (SO2) emissions would be nearly eliminated (99% reduction) from the largest point sources at these facilities." CATF, "Air Pollutant Reductions From Carbon Capture," 2023.

[79] "Expand advanced reactions, catalysts, and reactor systems to improve reaction performance in addition to reducing carbon emissions and improving energy efficiency." DOE, n.d.

been relatively more cost-effective. First-of-a-kind projects are starting to be deployed, which will provide evidence to determine cost-effectiveness in the near future.[80]

- **Efficacy of government funding support:** We think it is likely that most low-carbon production switches will make industrial processes and products more expensive, at least in the short term. We are uncertain whether government subsidies, policy support, and/or market demand will be large enough to incentivize the adoption and scale-up of these new interventions. We think it is quite possible that, for some heavy industry products, government funding support does not cause a "tipping point" whereby the private sector adopts new low-carbon practices at scale.

- **Geographic focus:** We evaluate interventions based on both direct impact and spillover effects. However, measuring spillover effects can be difficult and may be particularly important for many decarbonization efforts where we expect domestic innovation or regulation to have global impacts. We may be wrong about the degree to which US and EU policies have global spillovers, in which case there may be a more optimal strategy that focuses philanthropic efforts predominately at sources of GHG emissions (where, as discussed above, philanthropic funding has also been relatively low). We are uncertain regarding the relative effectiveness of focusing on geographies with stronger potential for innovation and more momentum behind heavy industry decarbonization versus geographies that are manufacturing hubs and where climate philanthropy is more neglected.

- **General equilibrium effects:** We think it is likely that decarbonization policies and incentives will differ across regions and countries, resulting in non-uniform adoption of low-carbon industry as well as large variances in demand, supply, and cost. It is possible these differences could normalize into a relatively lower-carbon global heavy industry. However, it is also possible that reduced demand for high-carbon products could cause prices to drop for these products, resulting in dual low-carbon/high-carbon economies.[81] We think the likelihood that this occurs varies substantially by industry and effort, and, in general, we are highly uncertain regarding the implications of this potential scenario in terms of GHG emissions, economics, and geopolitics.

- **Heavy industry regulatory code:** For certain heavy industry products and use cases (e.g., cement used in buildings), there exist rigid regulatory codes and standards. Given that often "compliance is a function of the material composition…rather than their engineering performance," it is unclear if, how much, and how quickly regulatory schemes might change to accommodate alternative

[80] LeadIT, "Green Cement Technology Tracker," n.d.

[81] "However, unlike for technology, policy mechanisms with the same goals can work at cross purposes. For example, carbon border adjustment mechanisms can penalize low-carbon products that do not face carbon prices at home. Conversely, the technology subsidy in one country can exceed the carbon price benefit offered in another. Both of these possibilities are barriers to trade in low-carbon products." Gross, Brookings, 2021.

low-carbon industrial materials.[82] Our understanding is that there has been progress on adjusting standards for novel, low-carbon concrete.[83]

Bottom line / next steps

We have identified heavy industry as a priority impact area and therefore plan to consider organizations working on industrial decarbonization for both Top Recommendations as well as grantees from the Giving Green Fund. Heavy industry is a substantial GHG contributor, and we think there are relatively high-leverage opportunities to affect corporate and government spending and decision-making that can productively absorb additional philanthropic funding. We think cost-effectiveness likely varies substantially by industry and intervention and are especially uncertain about the cost-effectiveness of R&D efforts, the efficacy of government funding support, geographic focus, general equilibrium effects, and heavy industry code.

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[82] "Restrictive building codes and standards wherein compliance is often a function of the material composition (e.g., OPC-based chemistries) rather than their engineering performance." National Academies of Sciences, Engineering, and Medicine, "Mineral Carbonation to Produce Construction Materials," *Gaseous Carbon Waste Streams Utilization*, 2019.

[83] "The Colorado-based company Prometheus Materials utilizes algae to produce masonry blocks that achieved ASTM C129-22, Standard Specification for Nonloadbearing Concrete Masonry Units, and C90, Standard Specification for Loadbearing Concrete Masonry Units performance requirements." Lecamwasam, "Researchers are developing promising solutions to concrete's high greenhouse gas emissions — one is ready to scale," ClimateWorks, 2024.

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