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Policy Packages for Decarbonizing Heavy Industry

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Abstract

The Paris Agreement's primary goal is to keep the rise in average global temperatures to "well below 2°C and toward 1.5°C" from preindustrial levels. If this goal is to be realized, the industrial sector must achieve net-zero carbon dioxide (CO_2) emissions by 2055. Consequently, and given the 15–25-year lifespan of major process equipment, any new investments in industrial production must aim for near-zero emissions by the early 2030s or compensate for emissions through additive, verifiable and permanent negative offsets. Tailored approaches at the sectoral, regional and developmental levels are necessary, including improved **material efficiency**, enhanced recycling in both quantity and quality (i.e. transparent **circularity**), and the **decarbonization of production processes** while maximizing energy efficiency. This, in turn, requires the electrification of existing processes, transitions to ultra-low GHG-emitting fuels and feedstocks, and the adoption of carbon management strategies such as carbon capture and storage. These strategies will also significantly contribute to improved local air quality.

Key Messages

1.
Decarbonizing industry is technically possible but hinges on bold policy actions and transformative innovation.

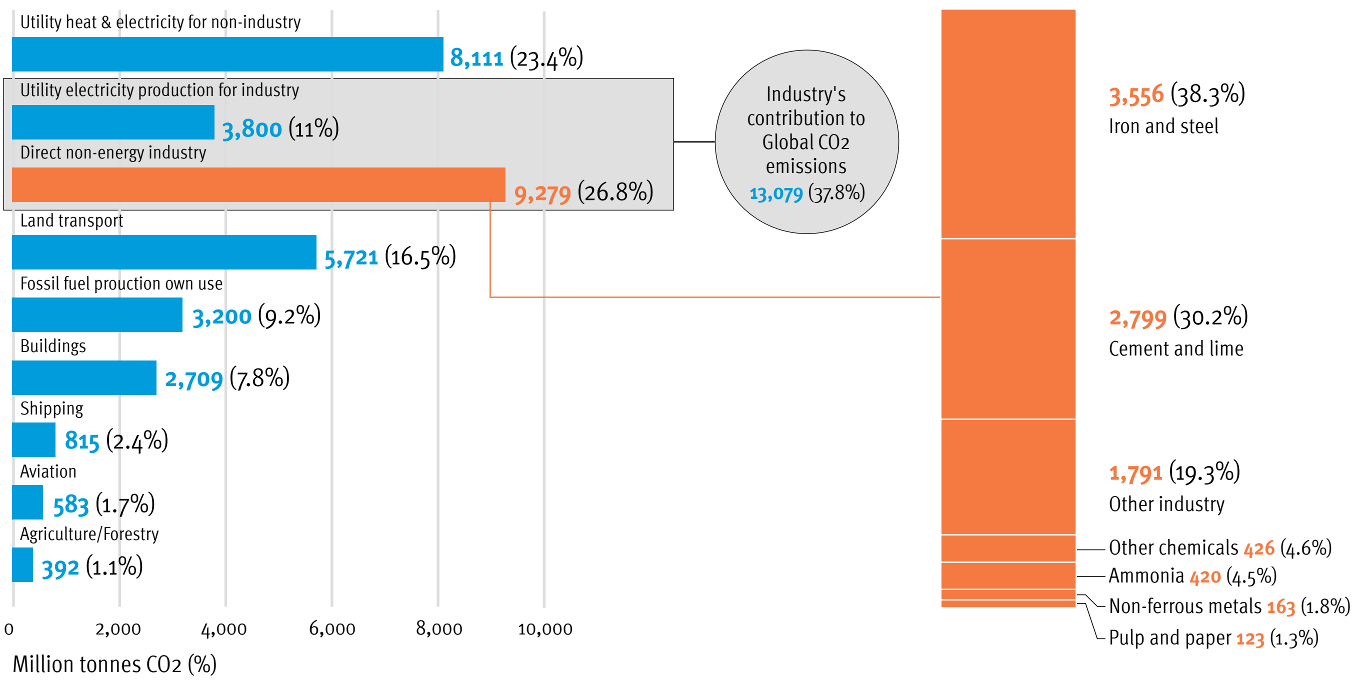
2.
Effectively decarbonizing industry holds the potential of reducing global CO_2 emissions by 30 per cent, but calls for demand and supply side policies.

3.
High-income industrialized economies must provide financial assistance to support the adoption of zero-emission technologies in developing countries.

Heavy industry and the Paris Agreement goals

About 1/3 of global combustion and process CO_2 emissions originate from non-energy production industries, with 70 per cent stemming from industries commonly referred to as "heavy", "hard-to-abate" or "hard-to-transition", such as steel, cement and chemicals (see Figure 1). Prior to the signing of the Paris Agreement in 2015 during COP21, heavy industry was largely excluded from most global emission reduction initiatives. It was assumed that it would operate within the remaining 20% of allowable emissions or rely on negative emissions generated by the electricity sector (i.e. via biomass combustion power generation with carbon

FIGURE 1: INDUSTRY'S CONTRIBUTION TO GLOBAL CO_2 EMISSIONS, 2020



Note: The share of electricity production allocated to industry is based on 2019 data, reduced by 5% to reflect decreased industrial production and slightly lower electricity GHG intensity. The figure focuses on energy and industrial process emissions, and does not include land use change and forestry.
Sources: Authors' elaboration based on IEA (2023), "Detailed CO_2 estimates", IEA CO_2 Emissions from Fuel Combustion Statistics: Greenhouse Gas Emissions from Energy (database)

capture and storage).[1] The Paris Agreement, however, called for a drastic shift in emission reduction policies by committing to net-zero emissions by 2055 to keep +1.5°C within reach, thus demanding an equivalent cut in greenhouse gas (GHG) emissions from heavy industries. This is technically possible but rests on improvements in material efficiency, enhancing circularity and decarbonizing production processes.

The basic idea behind improved **material efficiency**—a concept that is considered a key component of the circular economy in certain discourses but which we treat as a distinct concept here to narrow down where policy must be applied—is producing the same end-use service with fewer GHG intense materials. This can be achieved through various means. Ecodesign, which entails assessing and subsequently reducing a product's environmental footprint over its life cycle[2] through conscious design and revised building codes and regulations[3], is one strategy to reduce the use of carbon-intensive materials. Material efficiency can also be improved by maximizing the lifetime and reusability of materials, i.e. by i) extending the lifespan of products and structures; ii) minimizing rebuild cycles, and iii) promoting adaptability for other potential end-uses (e.g. using movable walls and large accessible conduits), thus allowing for non-destructive reuse and more effective recycling of existing structures' components.[4] Finally, from a whole structure GHG intensity perspective, switching to less GHG intense materials where possible, e.g., wood, local natural materials, and cementitious material substitutes, can be used to reduce overall emissions.

Another strategy to mitigate emissions from heavy industry is fostering **circularity** by increasing both the quantity and quality of recycling of materials with high GHG emissions, including metals (e.g. iron, aluminium and copper) and plastics (e.g. polyethylene, polyvinyl chloride and polypropylene), while continuously expanding the use of recycled materials through initiatives such as deposit schemes, design standards and producer end-of-life responsibility policies.[5]

GHG emissions can also be lowered by **decarbonizing production processes**, e.g. through research, development and commercialization of emerging and near-commercial technologies[6] that produce zero or very low emissions. "Near commercial" technologies are in fact often already being applied in production processes (e.g. electric boilers and heat pumps), but their use is limited due to relatively high market prices for electricity or because they are subject to regulation. "Emerging" technologies, on the other hand, refer to recently developed technologies that are still in the research and development phase and are thus not yet available for commercial use. These technologies rely on low GHG electricity, hydrogen, biomass and/or carbon capture and storage or utilization (e.g. hydrogen direct iron steel or post-combustion carbon capture, utilization and storage (CCUS)).

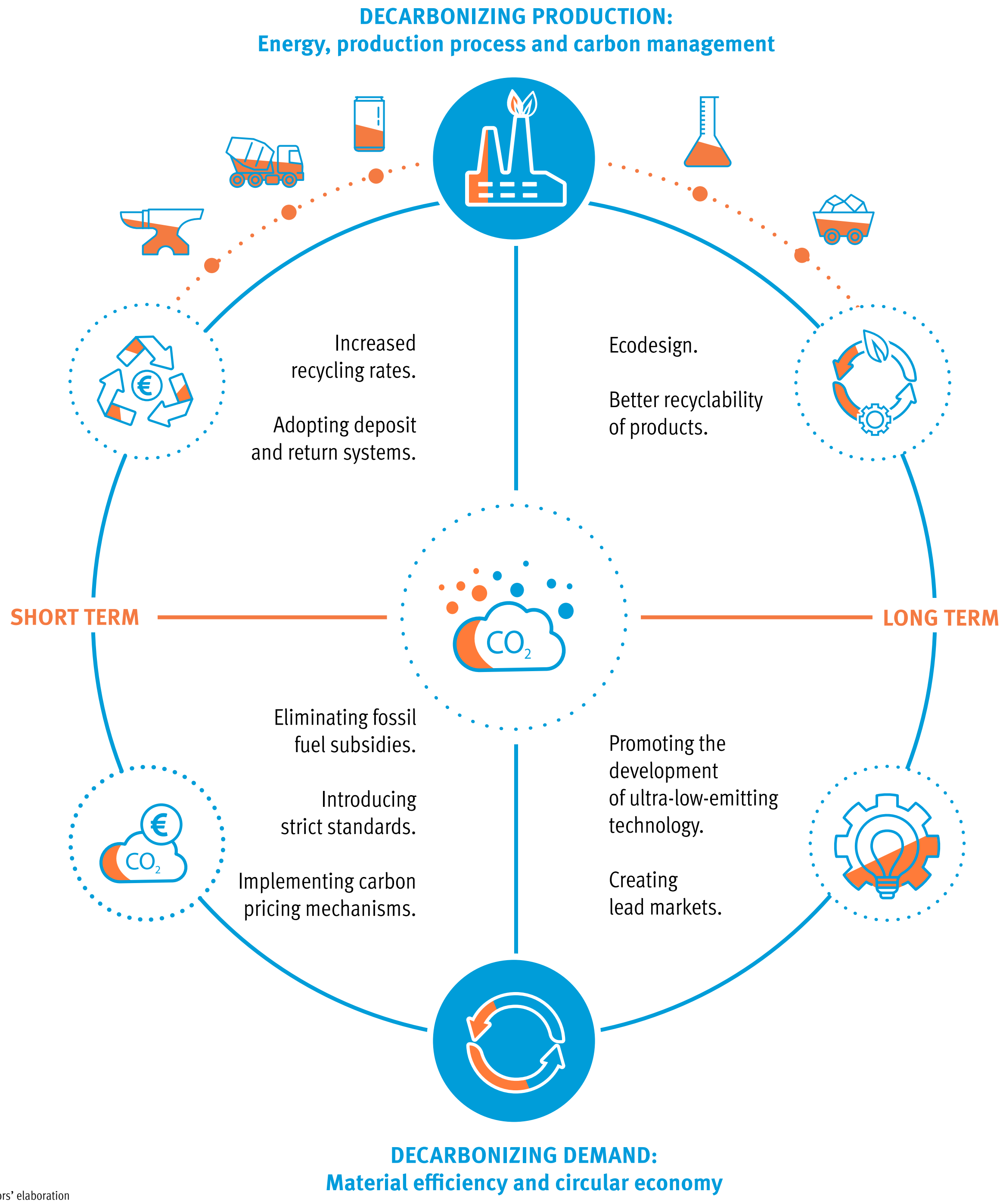
Each of these strategies requires a transformation of the entire supply chain to minimize costs and risks while ensuring adequate profits for reinvestment to meet ongoing demand.[7] A restructuring of supply chains could involve the production of the most GHG-intensive materials in regions with a favourable geology for carbon capture and storage or abundant clean electricity sources to drive alternative processes[8], which can then be distributed to other regions for further upgrading and consumption. This transformation requires a departure from the "silver bullet" approach. Policies and initiatives cannot implement a "one-size-fits-all" approach to achieve the decarbonization of heavy industry; they must incorporate a range of technologies and solutions that can be tailored to different regions, depending on their unique industrial structure, resource availability, and political and economic conditions.

Industrial decarbonization requires a multi-pronged material efficiency, circularity, and production decarbonization approach.

Combining demand- and supply-side policy interventions

Policy packages for decarbonization should target both i) the demand side (demand for material efficiency and circularity) and ii) the supply/production side (energy efficiency, electrification and fuel switching using known technologies; adapting production processes to facilitate the use of low GHG energy sources; and carbon management strategies, e.g. carbon capture and utilization or permanent geological storage) (see Figure 2).

FIGURE 2: POLICY PRIORITIES FOR DECARBONIZING HEAVY INDUSTRY IN THE SHORT- AND LONG TERM



Source: Authors' elaboration

Commencing at any point in the circle is possible, as all strategies must eventually be pursued, but a logical starting point could be increased recycling in the short term and the implementation of eco-design for new products in the long term. A focus on inexpensive, widely available, and high-volume clean electricity generation also supports the components of industrial decarbonization.

> In the long run, the goal is to use as little new material as possible, make things last in a reusable & repairable way, and recycle as much as possible at the highest quality possible, all driven by clean energy.

Decarbonizing demand

Decreasing demand for GHG-intense materials such as steel, concrete and plastics is a first step towards reducing emissions. This can be achieved through both short- and long-term strategies: in the short term, policy efforts should focus on increasing recycling rates by improving and expanding collection and sorting networks for recyclable waste materials (e.g. for steel, aluminium, copper and other metal scrap and clearly labelled plastics) as well as by encouraging the adoption of deposit and return systems. Policies for decarbonizing demand in the long term should promote eco-design and improved recyclability of products. The substitution of higher carbon products can thereby be maximized, i.e. the use of carbon-intensive materials minimized and repairability promoted by facilitating the non-destructive reuse of products. The quality of recycling can be improved by simplifying the separation of product subcomponents (e.g. cars' copper components, such as wiring, could be designed to be easily separable and detachable before being disposed). Such policies will need to be co-designed together with building and vehicle regulators, architects, civil, structural and industrial engineers, designers and firms that will need to implement them.

Decarbonizing supply

Policies aimed at decarbonizing production processes in the short term include eliminating fossil fuel subsidies, introducing stringent maximum GHG intensity standards, and gradually yet steadily implementing carbon pricing mechanisms for all combustion and process emissions (through carbon levies, cap and trade systems, or capped and tradable performance regulations) combined with competitiveness protection measures (e.g. border carbon adjustments). These measures can also serve to restructure the market and promote energy and material efficiency, recyclability, circularity and innovation in the production and consumption of materials. However, current technologies—unless they are electric—are limited in terms of their ultimate capacity to eliminate emissions. Hence, policies should support the development of next generation, ultra-low-emitting processes through research, development and commercialization (e.g. CCUS or electrification-based processes powered by zero emissions generation). Creating lead or niche markets paying attractive premiums in the short run will be key. These premiums could take the shape of contracts-for-difference or production tax credits to support early investment in more expensive technologies that have the potential to set new benchmarks for best available technologies, thereby increasing both awareness and expectations for the entire sector.

Planning and coordination among all stakeholders

Policy actions will need to be coordinated along supply chains and across regions. While the initial step involves the establishment of feasible technical pathways at the regional level, robust business models must be identified for all supply chain participants and components. Decarbonizing demand and production requires the retraining of civil and structural engineers, architects, designers, construction companies, manufacturers, traders and workers so they can incorporate new methods in the performance of their work. The industrial landscape must be restructured so stakeholders can supply the necessary products. Decarbonizing demand and production also requires cooperation between various stakeholders, including the government, firms, labour unions, indigenous groups, sector associations and civil society to implement effective, well-designed and just policy packages. Government will play a fundamental role in developing and coordinating the transition strategy, raising awareness and providing incentives for firms and key stakeholders to adopt new technologies to decarbonize heavy industry, and in establishing the regulatory framework so these technologies can be effectively used.

Policy priorities for countries at different stages of development

The context for decarbonization varies considerably between industrialized, emerging and less developed countries, especially given that the latter two country groups are expected to account for the majority of new demand.[9] Each country group pursues distinct priorities and approaches when it comes to the industrial sector (see Table 1).

High-income industrialized economies[10]

The primary responsibility of high-income industrialized economies in the short- to medium term is to develop research, development and commercialization initiatives to achieve very low and zero emissions in the steel, cement, aluminium and chemical industries based on best available technologies (BAT).[11] This entails introducing performance regulations to provide guidance; creating lead markets; offering targeted finance; and incorporating land use planning to encourage industrial clustering which facilitates the sharing of infrastructure for electricity, hydrogen, carbon capture and storage/utilization, and the reuse of waste heat. Using the steel industry as a case in point, primary markets for green iron and steel can be established for government procurement by implementing infrastructure content regulations and offering public premium pricing mechanisms, such as contracts for difference or production tax credits similar to those for energy technologies in the United States Inflation Reduction Act.[12] Car manufacturers could be encouraged to commit to buying green steel as it becomes available and to design vehicles that can be readily disassembled for recycling purposes. Collaborative efforts in the cement industry between the government, building code regulators, cement manufacturers and cement users are key to optimize the use of cementitious material substitutes such as slags and LC3 cements[13], and to encourage the adoption of CCUS or eliminate emissions associated with cement production. Alumina electrolysis and the use of low GHG electricity and inert electrodes should be promoted in primary aluminium production, while aiming to achieve a recycling rate of 90 per cent or higher for aluminium containers. To realize net-zero emissions in the long run, the chemical industry will have to be incentivized and subsequently mandated to maximize the use of recycled feedstock inputs (e.g. recycled plastics), biogenic fuels and feedstocks as well as low GHG electricity, hydrogen and carbon sources.

American and European Union trade and climate industrial policy has been rapidly evolving, with the U.S. having passed the Infrastructure Investment and Jobs Acts (2021), CHIPS (2022) and Inflation Reduction Act (2022), and the EU tightening the Emissions Trading System to ~ EUR 90 per tonne CO_2, and initiating the measurement process to implement the Carbon Border Adjustment Mechanism, while also adopting the Green Deal Industrial Plan in direct response to the IRA. This has led to some unresolved trade conflicts.[14] Other high-income industrial countries have been responding in a similar vein to both decarbonize their economy and

High income countries, reflecting their historical cumulative emissions and capacities, need to the lead the way with new technology and finance, but lower income countries need to use the tools that are available to avoid developing a high GHG intensity industrial structure.

maintain competitiveness. There are as of yet only limited signs of cooperative efforts to decarbonize heavy industry, but these countries have sufficient capital and capacity to achieve industrial decarbonization using their collective resources. China is not technically a high-income country but is one of the most active in terms of deliberate production and uptake of clean energy technologies and should therefore be included in this group.

Upper middle-income industrialized and industrializing economies

Middle-income countries span a wide income range, with some being highly industrialized and others just beginning the process. Although some may be, this country group is generally not involved in research, development, and commercialization. Upper middle-income countries should at minimum prioritize the adoption of best available ultra-low emissions technologies in line with their existing resources, and potentially with targeted financial support, if necessary. Several of the world's largest steel and cement multinationals are based in middle-income countries (e.g. CEMEX in Mexico and Tata in India) and are fully capable of building near-zero emissions facilities when incentives are available. They should collaborate in piloting innovative, very low and zero emissions technologies in real-world settings (e.g. use of CCS- ("blue") and electrolysis- ("green") based hydrogen for iron ore reduction and ammonia for fertilizers), particularly in regions with abundant renewable resources for generating electricity.[15] Middle-income economies should maximize their recycling networks for steel products as vehicle and buildings reach their end-of-life and leverage these resources to advance the development of secondary steel industries. Regulations for the cement industry should be introduced to standardize local concrete premixes tailored to local mineral resources, and to monitor and limit the use of bagged cement. Effective deposit and return systems for glass, aluminium and plastic beverage containers should be set up and strictly enforced. Raising awareness and encouraging the adoption of lower GHG emission sources in the chemical industry, including natural gas and natural gas liquids instead of coal and crude oil, should be promoted to accelerate the transition towards environmentally friendly alternatives. Finally, middle-income countries should embrace mining technologies with minimal GHG emissions, supported by financial incentives and direct funding to facilitate their adoption.

The crucial question of who should pay for the additional upfront and potential operating costs (depending on the cost of energy) of first generation near-zero emitting industrial facilities in middle- and low-income economies—where capital is systematically more expensive and where the capital that is available is prioritized for basic needs and infrastructure—remains open. Something akin to the Just Energy Transition Partnership (JETP) is needed, but for industry, i.e. a purpose-built finance mechanism for decarbonizing heavy industry, perhaps a Just Industrial Transition Partnership (JITP).

Lower middle-income and low-income economies

For low middle-income and low-income countries, while the adoption of advanced near-zero emission plants should be considered, the decarbonization discourse is largely about clean energy, clean buildings and the establishment of recycling networks. These economies should prioritize capacity development to supply clean energy to households, businesses and industries by upgrading essential supply infrastructure and establishing institutions that promote, enforce and monitor low- and zero emission standards. Greening the production of steel can be achieved by creating networks to collect different grades of steel for recycling and setting up depots to collect end-of-life vehicles and machinery, and where residents can drop off their recyclables and receive deposit refunds. Likewise, cash incentives for glass, aluminium and plastic recovery should be offered to motivate the return of beverage containers for recycling. Moreover, additional collection points should be set up. Cement and concrete production must be professionalized by raising awareness; promoting the use of professional concrete mixing over traditional practices, where clinker substitution can be maximized; establishing regulatory bodies and implementing capacity measurement systems. Finally, lower middle- and low-income countries should ban one-use plastics where feasible, given the absence of recycling infrastructure, and educate farmers about methods to reduce the use of ammonia-based fertilizers while sustaining crop yields.

TABLE 1: POLICY PRIORITIES FOR HEAVY INDUSTRY DECARBONISATION, BY STAGE OF DEVELOPMENT

	CROSS-CUTTING	Steel	Cement	Aluminium and nonferrous metal smelting	Chemicals	Resource extraction
ALL	Supporting the development of a zero emissions industry and commodities trade system. Planning for geographically co-located industrial clusters, based on existing centres. Identifying regions with appropriate resources for low emissions commodity production.	Maximizing low contamination iron product recycling through advanced deposit and return fee systems.	Reviewing building codes to allow for higher concentrations of substitute cementitious materials. Grinding up cement for reuse as cementitious material and maximizing recarbonation. Educating firms on how to maximize concrete strength and minimize use.	Maximizing aluminium recycling through advanced deposit and return fee systems. Avoiding aluminium made with coal electricity. Regulating use of inert electrodes when available. Implementing heat management to provide flexibility to electric consumption in aluminium plants.	Banning single-use plastics. Maximizing ethylene and poly vinyl chloride recycling. Educating farmers on how to minimize ammonia-based fertilizer use and move from urea to ammonium nitrates with lower CO_2 emissions. Implementing heat management systems to maximize efficiency and allow heat cascading. Encouraging low GHG feedstocks (e.g. NGLs vs. coal) through carbon valuation	Electrifying mining, heavy duty vehicles and general motor drive end uses.
HIGH-INCOME INDUSTRIAL ECONOMIES	Lead R, D & C to push BAT to very low and zero emissions. Providing targeted finance. Performance regulations for steam to encourage industrial clustering, heat sharing, heat pumps and electric boilers.	Establishing lead markets (e.g. green purchasing, feed-in-tariffs, CfDs, and infrastructure content regulations). Incentivizing automakers to design cars that are easy to disassemble before scrapping. Support R, D, & C of zero emission steel technologies.	Training architecture and building professionals on how to prioritize material efficiency and circularity, along with electrification and building self-energy supply. R, D, & C of new cement chemistries, prioritizing negative ones.	R, D & C on hydrolytic and electrolytic smelting technologies. Target 90%+ return of aluminium containers through increased deposits and efficient recovery systems.	R, D & C of biogenic and DAC-based electro fuels and feedstocks. Using regulation or pricing to shift all feedstock hydrogen production (e.g. for fertilizer) to lower and eventually to net-zero hydrogen in the long run.	R, D & C for hydrolytic and electrolytic smelting.
UPPER MIDDLE-INCOME ECONOMIES	Implementing BAT using zero GHG technologies and targeted finance as necessary . Piloting new very low and zero emissions technologies in a real-world environment.	Formalizing recycling networks. Establishing secondary steel industries based on scrap to feed with zero GHG pig iron at a later date.	Regulating the cement industry to industrialize local concrete premixes optimized for local resources, including maximizing cementitious material substitution. Tracking and limiting the use of bagged cement.	Establishing and enforcing deposit systems to encourage return of aluminium beverage containers.	Promoting awareness and use of lower GHG feedstocks (e.g. transition from coal and crude oil to NG and NGLs, and eventually bio- and DAC-based feedstocks). Globally targeted subsidies as necessary to encourage use of green ammonia for fertilizer production.	Adopting very low GHG mining technology, with targeted subsidies.
LOW AND LOWER MIDDLE-INCOME ECONOMIES	Implementing BAT using zero GHG technologies and targeted finance where possible. Building institutions to allow implementation of new near-zero emissions BAT standards, including measurement, monitoring, and enforcement.	Developing capability to establish recycling networks for various grades and types of steel. Setting up depots for recycled steel and paying deposit return fees.	Building institutions to support professional industrialization of cement and concrete production, e.g. education systems, regulatory bodies, capacity development and measurement systems.	Introducing deposit systems to encourage return of aluminium beverage containers. Establishing depots for recycled containers and paying deposit return fees.	Banning single-use plastics, prioritized due to lack of recycling networks. Educating farmers on how to minimize ammonia-based fertilizer use and to move from urea to ammonium nitrates with lower CO_2 emissions.	

Abbreviations: **BAT**, best available technology; **CfDs**, contracts for differences; **DAC**, direct air capture; **GHG**, greenhouse gas; **NGLs**, natural gas liquids; **R,D & C**, research , development, and commercialization; **TRL**, technology readiness level. Country groups based World Bank's income classification.

Source: Authors' elaboration

Conclusion

Effective industrial decarbonization requires collaboration between high-, middle- and low-income countries. The highest income countries have the most historical responsibility for GHG emissions and must take accountability by providing financial aid and resources to promote research, development and commercialization to achieve zero-emission BAT. All countries, however, will be responsible for adopting and implementing such technologies, with high-income countries providing investment and operating support for the earliest applications. Collective efforts involving a wide range of industries and actors—government, private sector, international organizations and the research community—are necessary to accelerate the use of efficient materials. Well-designed policy packages that include investments in research and development to implement new technologies such as CCS, the promotion of knowledge sharing, technological transfer and capacity development as well as the establishment of international standards and regulations are crucial if hard-to-abate industries are to decarbonize. It is only through collective efforts that the Paris Agreement's objective of keeping the global temperature below +2.0°C and closer to +1.5°C can be met.

Endnotes

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