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A programmatic approach to enhance international climate cooperation: lessons from three system transformation studies in Mexico

Daniel Buira, Jordi Tovilla, Thalia Hernández (Tempus Analítica), with contributions from Ana Pérez Català & Marta Torres Gunfaus (IDDRI)

The Paris Climate Agreement's first Global Stocktake challenged the international community to transition away from fossil fuels (TAFF) and to enhance international cooperation. How can this be done, while aligning with national pathways? This *Study* focuses on Mexico's related challenges through three systems transitions (renewable energy, electric public transport, green iron and steel) which are necessary for the country to shift its development pathway in line with its 2050 climate goals. Analysis of the changes needed and barriers to success unveils the international cooperation actions most effective at enabling rapid and large-scale transitions.

KEY MESSAGES

Delivering system changes requires detailed programmatic planning of short and medium-term actions to achieve long-term objectives through a sequence of actions across planning, regulation, investment, and implementation over years and decades. Dedicated in-country capacities need strengthening.

Rolling out renewable power quicky enough to reduce current fossil-fuelled generation requires a rate of investment that exceeds the Mexican Government's available fiscal space to for this purpose. However, Mexico's abundant renewable resources mean the resulting energy will be competitive. International cooperation could boost rollout by ensuring sufficient volume of international public and private finance can complement the investments of the Mexican state in renewable generation and new transmission infrastructure without increasing Mexico's cost of capital.

Shifting urban passenger transport to electrified public transport in Mexican cities will also require high investment in enabling infrastructure and electric vehicle fleets. With many LAC cities facing similar challenges, there are opportunities for regional coordination to boost local supply chains and capture a greater share of the resulting manufacturing activity, promoting economic growth.

Decarbonizing iron and steel needs the supply of green Hydrogen (GH2) to power the smelting of iron ore to create iron and primary steel. Although Mexico should be competitive in the production of GH2 from renewable electricity, it will remain more expensive than the fossil alternative, at least in the short term. Both internal and international trade conditions will be needed to boost initial GH2 and Green Iron and Steel facilities without causing undue price increases in end-markets, requiring coordinated international cooperation on tariffs.

Based on these three case studies, six types of interventions are described which can enhance the impact of international cooperation in accelerating in-country TAFFs by aligning it with national pathways. These relate to: (1) financial support to reduce the cost of capital available; (2) financial support to increase the volume of capital available; (3) capacity building support for in-country planning and institutional capabilities; (4) technology and implementation support for new low-carbon product and industry development; (5) trade support to boost the viability of new low-carbon products and industries; and (6) collaborative governance structures to guide effective international cooperation.

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EXECUTIVE SUMMARY

This paper explores how international climate cooperation can be enhanced in line with the outcome of the first global stocktake (GST1) to better support developing countries to achieve an equitable transition away from fossil fuels. It studies three system transformations that Mexico must achieve over the next 25 years to deliver on its climate commitments–namely the very rapid rollout of renewable electricity generation, the shift of passenger demand to electric public transport, and the production of iron and steel using green hydrogen–to extract common learnings for economy-wide system change, and from there to identify how international cooperation can best strengthen this country-led process.

The three case studies show that achieving these transformations requires a coordinated planning and implementation approach, with a common aspiration of system change guiding diverse stakeholders and their actions over the short, medium and long term. This calls for a different way of coordinating action both within and across public and private sectors, with an explicit recognition of the common goals and the role each step plays within a broader programme. We therefore call this a "programmatic" approach.

A programmatic approach starts from country-level needs and bottom-up transformation pathways, linking actions across policies, institutions, markets and investment to deliver system-wide change. It moves beyond fragmented, sector-siloed, project-by-project support towards cooperation frameworks explicitly designed to deliver system transformations at scale and speed. International cooperation should therefore be closely aligned with the national vision of change, supporting countries to elaborate and continuously improve their low-emissions development pathways while also supporting the implementation of actions within these pathways.

The case studies demonstrate that different transformations require different combinations of international cooperation action. The rapid rollout of renewable electricity requires a step-change increase in infrastructure investment, with large-scale and innovative financial support needed to mobilize sufficient capital without increasing Mexico's cost of borrowing, alongside support for energy system planning and institutional capabilities. The shift to electric public transport presents different challenges: it requires changes in urban planning and infrastructure, while regional aggregation of demand can create a large-scale market for local industry and supply chains, supported by cooperation on standards, procurement, financing, technology and capacity building. Producing green iron and steel using hydrogen requires coordination of green hydrogen supply, industrial capabilities, market creation and international trade, with international cooperation helping to reduce technology and market risks and support access to new global markets.

Common findings across the three case studies suggest six types of intervention through which international cooperation can contribute to a programmatic approach, in collaboration with developing countries and in light of country needs:

1. Financial support to reduce the cost of capital available;
2. Financial support to increase the volume of capital available;
3. Capacity building support for in-country planning and institutional capabilities;
4. Technology and implementation support for new low-carbon product and industry development;
5. Trade support to boost the viability of new low-carbon products and industries; and
6. Collaborative governance structures to guide effective international cooperation.

These interventions are mutually reinforcing and need to be combined to meet the barriers, opportunities and risk profiles of particular transformation pathways over time. More finance alone will not be sufficient where institutional capacity, enabling infrastructure, technology, markets or trade conditions constrain implementation. Conversely, where domestic fiscal space and local financial markets are insufficient, international cooperation must enable access to additional volumes of capital and reduce perceived risk and the cost of capital for priority investments.

Delivering effective interventions at scale will require a high level of coordination among multiple stakeholders. International cooperation should therefore support not only the investments and actions within national transformation pathways, but also the in-country institutional architecture needed to manage their interdependencies over time. Strengthened collaborative governance can provide a balance between long-term ambition and practical short-term goals, while ensuring that international support remains connected to the national vision of system change.

The programmatic approach raises the bar for both recipients and providers of international cooperation. Developing countries need to strengthen their sustainable development pathways and identify the country-level needs required to achieve Paris-aligned transformations. At the same time, developed countries and development agencies should use these national transformation plans to guide the planning and implementation of international climate cooperation, creating a shared narrative of change and coherent packages of support.

Joining up national decarbonization pathways with international cooperation can help enhance the ambition and scale of the national programme of change while pursuing economic, social and environmental objectives in parallel. The three Mexico case studies show how international cooperation can be included within bottom-up system transformation programmes, with different combinations of finance, capacity building, technology, trade and governance support tailored to the needs of each transformation. The programmatic approach thus provides a way to connect country-led visions of system change with coordinated international cooperation capable of supporting their implementation at the scale and speed required.

1. A PROGRAMMATIC APPROACH TO ENHANCE INTERNATIONAL CLIMATE COOPERATION

Enhanced international cooperation is necessary to achieve the Paris Agreement goals

The outcome of the First Global Stocktake (GST1) highlights the need to enhance international cooperation[1] as a key to unlock more effective global climate action. The IPCC has set out criteria to assess the effectiveness of international cooperation in enabling climate goals (Patt *et al.*, 2022). These include achieving identifiable environmental benefits such as economy-wide and/or sector-wide reductions of greenhouse gasses (GHG) while also promoting economic growth and improving distributive outcomes. Delivering these benefits on a timeline and scale consistent with Paris Agreement goals requires international cooperation to contribute to the transformation of national economies towards zero-carbon and sustainable development pathways. International cooperation can also help establish the institutional frameworks needed to drive these transformations.

International cooperation must work from country-level needs to ensure cooperation action enables change and development on the ground. Such "needs-based" cooperation can ensure solutions are designed to address the priority requirements of countries, taking into account the specificities of different national circumstances. It also recognizes the need to prioritize cooperation solutions that provide local benefits, effectively supporting the development of economic activities in the country and responding to the needs of the local populations (DDP, 2023).

An important challenge faced by many developing countries when seeking to increase the scale and impact of international climate cooperation lies in the difficulty of planning and implementing deep coordinated transitions across sectors that are capital intensive, politically visible, and institutionally complex. Developing a national decarbonization pathway for a whole-economy transformation can help countries establish short, medium, and long-term actions that work in a coordinated manner to guide the transition. These long-term pathways will be key to identify not only the domestic transformations required for decarbonization but also the international cooperation needed to make them possible. Packages of complementary policies, grouping together specific measures designed to overcome planning, institutional, regulatory, fiscal, and financial barriers to change, and thereby setting out sustainable development alternatives for citizens, businesses, and investors alike, will be necessary to operationalize these pathways (Waisman *et al.*, 2019). Envisioning such a multi-step programme of change not only helps stakeholders identify tasks and understand their role, but also to consider alternatives, as well as potentially contradictory actions to avoid.

National transitions must take place within a broader global shift towards net zero. In this context, the Long-Term Low Emissions Development Strategies (LT-LEDS) developed by countries provide a valuable opportunity for countries to communicate their ambitious pathways and to highlight the cooperation requirements that underpin these transformational pathways (Pérez Català *et al.*, 2024). Such plans must address the decarbonization of economic sectors while also tackling development priorities, setting out corresponding actions and policy measures.

A sound decarbonization pathway should thus be reflected in policy documents such as country LT-LEDS presented to the UNFCCC, as well as in NDC targets that lay out short and medium-term milestones required to achieve the LT-LEDS. Doing so will enable international cooperation to more closely align with the national vision of transformation. Currently, not all LT-LEDS documents contain the level of ambition and detail to guide enhanced international cooperation, nor do all NDCs align shorter-term goals with the long-term aims.

A programmatic approach can enhance international cooperation by aligning it with country needs, pursuing economic, social and environmental objectives in parallel.

A double challenge must thus be addressed to improve international cooperation for climate action in line with the outcome of GST1. Developing countries should strengthen their sustainable development pathways to identify their country needs to achieve Paris-aligned transformations. At the same time, developed countries and development agencies must use these national transformation plans to guide the planning and implementation of international climate cooperation.

Joining up national decarbonization pathways with international cooperation can address many of the challenges limiting the scale and effectiveness of current international climate cooperation. It requires moving beyond fragmented, sector-siloed, project-by-project support, towards new cooperation frameworks explicitly designed to deliver system transformations at scale and speed. This paper proposes a **programmatic approach** that aims to address these challenges in a coordinated manner. The main elements of this approach are:

- An ambitious national vision of change, based upon a bottom-up pathway grounded in local conditions, clearly delineating measures across the short, medium, and long term, leading to system-wide change;
- An implementation architecture that addresses interdependencies across policies, institutions, and markets; and
- A financing strategy that matches financial instruments to barriers, opportunities, and risk profiles over time.

This programmatic approach should be followed jointly by providers and recipients of international cooperation, creating a shared narrative of change to frame discussions and decisions.

[1] In this report, international cooperation refers to coordinated action by governments and international public, private and multilateral actors to enable and accelerate country-led system transformations, through financial, technical, technological, institutional, trade and governance support aligned with national development and decarbonization pathways.

International cooperation can support countries in translating existing climate plans and aspirations, such as their LT-LEDS and NDCs, into interlinked roadmaps showing barriers, opportunities, requirements, timelines, and interdependencies between regulation, institutional arrangements, societal and demand-side changes, prices, public and private investment, and opportunities for new economic activity.

In this programmatic approach, countries will use their decarbonization pathways to identify portfolios of projects that deliver value across economic, social and environmental criteria. Projects should be explicitly linked to broader sustainable development objectives, with governance mechanisms that enable feedback and strengthen long-term trust from investors and society. These portfolios can then be supported through international collaboration actions tailored to their objectives.

EXAMPLE OF THE PROGRAMMATIC APPROACH

If a country faces important barriers to renewable power generation due to limited transmission capabilities, international cooperation from different agencies should coordinate between potential international investors to ensure sufficient capital is available on viable terms for rapid infrastructure roll-out. At the same time, national policies with regards to power prices should be complementary to such a roll-out, ensuring infrastructure investments can obtain a return while helping those in society who are most vulnerable to potential price changes. This in turn may rely on additional but coordinated international cooperation to assist with the fiscal impacts of such a policy.

Countries can be supported by international expert groups and organizations in the design process of project portfolios to reduce domestic learning curves, increase consistency with best international practices and transparency. International organizations, funders and partners can also be involved in developing the business models to realize the projects, as well as networks of technical experts (for example, power grid operators, regulators, and research groups when planning the shift of the energy systems away from fossil fuels towards renewable electricity). These capacity building efforts should support developing country capabilities in both private and public sectors.

Key elements of this approach have been derived from transformation case studies in Mexico.

The programmatic approach outlined above has been applied to three system transformations in Mexico: financing for renewable energy generation, shifting to electric public transport, and producing green steel using hydrogen. The case studies map the actions required for planning and implementation and show how different forms of international cooperation can be combined to support system transformation.

While the interventions identified in these case studies include support across the means of implementation usually discussed in the context of the UNFCCC (finance, technology, and capacity building), the bottom-up approach of identifying specific actions, and combinations of mutually reinforcing actions, across both country and international stakeholders, allows to both further detail and extend the classification of interventions that must be deployed. The types of intervention a programmatic approach should consider are:

1. Financial support to reduce investment risk and the cost of capital

Most traditional financial flows from donor countries and institutions to receiving parties fall within this category. However, novel international cooperation must provide financial interventions that reduce perceived risk and the cost of capital for priority investments. De-risking instruments, including guarantees that cover an initial loss portion (i.e. a first-loss protection layer), can lower financing costs, accelerate deployment, and make investment pipelines bankable. This category also includes concessional and blended finance to attract private investment and use public funds strategically.

Developing countries can help to decouple project risk for specific investments, such as investment in renewable generation, from generic country risk, by enabling institutional arrangements that facilitate market acceptance and financial returns to the project, provided they yield the environmental benefits to merit this treatment, while promoting just transition goals.

2. Financial support to unlock additional volumes of capital

Cooperation must enable access to additional volumes of capital where domestic fiscal space and local financial markets are insufficient. Mobilizing institutional investors, strengthening domestic financial intermediation (including through national development banks), and using clear, replicable financing arrangements are key actions in this category. Where enabling infrastructure underpins multiple sectoral transitions, this support must also help structure and scale up contractual and regulatory arrangements that secure stable revenues for financing, notably for electricity transmission and distribution and other network assets.

Multilateral development banks, bilateral development finance institutions and plurilateral initiatives such as the Just Energy Transition Partnerships can support these efforts by coordinating large-scale financing packages and helping establish the contractual, regulatory and institutional arrangements. As before, collaboration on in-country institutional arrangements can provide market conditions to favour roll-out of such cooperation.

3. Capacity building support for in-country planning and institutional capabilities

Cooperation must invest in institutional and human capacities for planning and implementation. Strong evidence-based planning must be integrated into decision-making, rather than remaining isolated in advisory exercises. Capacity support should also help to implement best practices across key systems (for example, in protocols for bus electrification, or for the operation of an electric grid with a high share of renewable sources) that reduce transaction costs, secure safe and efficient operations, accelerate replication, and improve accountability of all parties involved.

Improved institutional capacity should include the ability to make the new rules credible and enforceable. Mandatory standards and clear regulatory frameworks reduce uncertainty, stabilize expectations across political cycles, and improve the bankability of transition investments. Capacity support should therefore extend to improve monitoring, verification, and accountability mechanisms that link resources to performance. Results-based approaches, monitoring and impact indicators, and independent audits can strengthen institutional trust and ensure that concessional resources translate into measurable climate outcomes.

4. Technology and implementation support for new low-carbon product and industry development

Cooperation must contribute to industrial capability development in strategic transition technologies such as electric mobility and green hydrogen applications. Beyond technology transfer, this includes strengthening domestic and regional supply chains, skills, standards, and innovation ecosystems, and enabling collaboration structures between public entities and private firms, and long-term engagement with academia, final users and other stakeholders. Industrial capabilities can reduce long-run transition costs, improve political durability through jobs and local value creation, and accelerate learning-by-doing across sectors.

Access to new global markets will play an important role in some sectors like green steel and green hydrogen. A programmatic agenda should help direct international cooperation efforts to adjust relevant domestic industrial capacities to increase competitiveness in these new global markets.

Joint R&D programmes are another form under which countries could associate successfully, especially if they find it hard to carry all the burdens and risks of a deep transition individually, for example for the development of electric bus technology and manufacturing across several countries in Latin America, Asia, or Africa. This gives local investors and firms the ability to supply into common markets of a larger scale than their own countries, while diversifying the risk across a broader investor base.

5. Trade support to boost the viability of new low-carbon products and industries

Industrial value chains require commodities and products to meet demanding specifications, with international competition playing an important role in keeping prices down. This gives incumbents an important strategic advantage, providing a proven supply to global demand while working to use existing assets in the most cost-effective manner.

New low-carbon processes to develop products and commodities to existing standards involve significant up-front costs to set up new assets, that may be difficult to recover without price support or other forms of additional income to the sale of the end-product on the open market. Since the rapid development of new products and industries for the low-carbon transition within developing countries is a fundamental requirement for a just transition, international cooperation must work to ensure international trade favours such new products from developing countries, while minimizing impacts on end-prices, and with sensitivity to the potential political challenges of being seen to favour new industries in foreign countries rather than boosting national industry and jobs.

This challenge requires dedicated case-by-case agreements across industries and groups of countries. As an example, the use of a carbon price to favour low-emissions steel will merely promote increased use of secondary (recycled) steel, but not promote the investment in necessary new capacity for green primary steel. Since developed countries already have saturation levels of steel per capita, their recycling industries will prosper while making steel more expensive in developing countries, particularly those with very low levels of infrastructure that require important inputs of new steel. Therefore, trading arrangements which involve preferential treatment of first plants of primary green steel from developing countries can keep any additional costs low by only supporting a few facilities, not the whole global secondary steel market, and favour the creation of a new green steel industry in countries with the most competitive access to the necessary natural resources.

6. Collaborative governance structures to guide effective international cooperation

Cooperation may need to facilitate the creation or strengthening of collegiate, practice-oriented institutions and coordinating bodies that feed in the programmatic implementation processes across sectors and jurisdictions. Existing international organizations can provide important functions, but the implementation challenge often requires more sector-specific and delivery-focused coordination mechanisms, including technical expert commissions, peer-evaluation arrangements that drive transparency, and standing platforms for problem solving and coordination. Such institutions can help bridge the gap between technical planning and political decision-making by constant dialogue with policy-makers and stakeholders in each country, while being an active part of the international collaboration architecture that maintains accountability and continuity across administrative and political periods.

The knowledge generated in these emerging institutions will be valuable to measure progress throughout the diverse objectives pursued in each project and to refine polices and interventions in the future.

The ability to combine the different types interventions and design specific collaboration instruments to meet country objectives will be key to drive change.

Delivering effective interventions in all categories at scale will require coordination among multiple actors. Multilateral development banks (MDBs) and international development agencies can help coordinate bilateral donors and international financial institutions around coherent packages that combine concessional resources, guarantees, and market instruments. Climate funds can complement these packages where grants or highly concessional resources are needed.

Capacity-building can be strengthened through coalitions of countries willing to adopt best international practices or with some experience (on transition planning, for example), assisted by plurilateral technical committees and independent expert panels. Specific agencies from developed or developing countries may contain expertise that should be shared: developed countries and international development agencies should provide the funds to enable them to do so.

Development of industrial capability can be accelerated and the costs involved reduced in partnership with countries and institutions with industrial innovation experience. Also by expanding patent and technology access mechanisms, and enabling international collaboration channels among firms and public institutions.

The ability of country public sector institutions to work together on common goals or "missions" will be another important success factor (Mazzucato, 2024).

The three case studies that follow present more detail on how these different interventions can work together across different system transformations.

2. CASE STUDIES

2.1. Mexico case study on financing renewable electricity

Decarbonization of electricity generation is key to decarbonize the energy economy.

Electricity generation is at the core of the energy transition towards a net zero future.

Decarbonizing the power sector is crucial not only because it is the single largest source of energy-related CO_2 emissions globally, (Clarke *et al.*, 2022) but also because a carbon-free electric network enables other energy uses to transition away from fossil fuels to zero-emissions energy. Accelerating this dual strategy of electrification and decarbonization of the power grid in parallel is necessary to limit global average temperature increase to between 1.5 to 2 degrees C by mid-century (IPCC, 2022).

Low-carbon electricity generation must be rolled out extremely quickly to rapidly reduce the carbon footprint of current fossil-powered generation, while also providing additional generation to meet growing demand from other sectors that electrify to reduce their own emissions, such as for example the demand from electric vehicles. (Clarke *et al.*, 2022)

Carbon free electricity today is feasible and cheaper than the fossil alternatives.

The price of technologies used to produce electricity from renewable sources like wind and sunlight have been falling consistently and their levelized costs of electricity is now competitive with fossil fuels in many instances. (IPCC, 2022)

Renewable electricity savings in comparison to fossil technologies come mostly from the avoided use of any fuels in the process. As electricity generation shifts away from the use of coal, oil and gas these savings can accumulate to reach notable proportions in the long-term. This shift from fossils to renewables can also increase local energy security in countries that import fossils fuels–with volatile international prices–and where renewables are a domestic asset.

Mexico's current grid is dominated by imported gas, despite the abundant solar resource.

Mexico's power grid runs primarily on cheap natural gas imported from the USA.

Mexico's oil industry expansion during the second half of the previous century was noteworthy. By the 1980s revenues from the royalties from oil extraction and the exports sales of crude oil had become a cornerstone of national development. With the regional integration brought about by the North American Free Trade Agreement (NAFTA) in the 1990s and the "shale boom", cheap natural gas imports from the U.S. grew rapidly; today this is one of the main fuels used in industry and accounts for close to 70% of electricity generation.

This is mostly done in the more than 35 GW of combined-cycle gas turbines in the country (40% of total generation capacity), but also in some other combustion-based generation technologies. Under current plans, gas-fired combined cycle plants will be the technology with the largest expansion to reach around 50 GW by 2038, (SENER, 2024) despite this hindering Mexico's objective to achieve net zero emissions by 2050. This reflects just how deeply the inertia of using incumbent fuels, technologies and planning strategies is ingrained in current practices and influencing decision making today.

However, Mexico has abundant and competitive renewable resources.

Across most of its territory, Mexico's annual solar irradiation (averaging 5.8 kWh/m^2) is far more significant than its oil reserves (SENER, 2023). This huge solar potential enabled bids of electricity production at very low cost when Mexico experimented with auctions of renewable resources a decade ago (SENER, 2017). Wind, hydro and geothermal potentials also represent important sources of energy, both currently (hydro) and potentially in the future (particularly wind power).

The perception that the natural intermittency of renewable energy makes it unsuitable for a reliable grid is declining. A high-renewables power system can be reliable and robust if properly planned, diversified and operated, supported by adequate transmission, storage and flexible demand (Buira *et al.*, 2021)

Finally, managing energy demand should be done through programs that incentivize the efficient use of energy and assets, while addressing the lack of resources and vulnerability of large portions of society.

Shifting to renewable generation requires a coordinated approach to overcome barriers and ensure sufficient financing.

Coordination between regulators, markets and investors will be needed to accelerate investment in renewables in Mexico.

Mexico's transition requires rapid investment not only in renewable generation but also in enabling infrastructure, including transmission, distribution and storage, alongside changes in electricity demand. A credible pathway for scaling renewables and phasing out fossil fuels will therefore need regulatory clarity, institutional capacity and financing mechanisms that can mobilize private investment at scale.

Barriers such as short-term investment horizons, weak or uncertain policy frameworks, and limited institutional capacity can raise perceived risks and increase the cost of capital for renewable projects in developing countries. (IPCC, 2022) In Mexico's case, a clear pathway for ramping up renewables and phasing out fossil fuels will need regulatory clarity and dedicated institutional capacity, without which the necessary financial resources will be difficult to mobilize. Redirecting existing capital from fossil assets towards low-carbon power needs improving policy credibility and market access in heavily regulated sectors (like electricity). When ownership rules, market entry, and tariff design are clear, stable, and favourable to renewables, capital allocation will align more readily with climate targets, including through increased private participation.

Besides higher investment needs, countries in Latin America share some specific barriers that make a transition to a climate neutral energy system harder: increased technological risk, increased country risk, lack of a critical scale of investment to accelerate development and roll-out, constrained fiscal space, and sub-optimal market conditions and enabling infrastructure.

These regional constraints point to an agenda to reduce the risk and the cost-of-capital which could include: transparent climate-risk disclosure; dependable planning and permitting; credible long-term targets; and fit-for-purpose auction and contracting frameworks. Together, these can lower the perceived risk and hence the Weighted Average Cost of Capital (WACC) for investments, enabling concessional, guarantee, and blended facilities to crowd in private finance at scale.

In terms of broader implementation, piloting the new ways of doing things to accelerate the transition will be key, including new business models, regulatory architectures, production and supply chains, retraining campaigns, and community engagement practices. This will provide valuable lessons towards a programmatic implementation approach around which decision-making of all stakeholders can align, from government agencies and regulators to private investors and final users.

Mexico's transition requires a coordinated portfolio of investments across the electricity system, each requiring coordination between internal policy enablers and international cooperation.

In general, Mexican authorities should review the rules for electricity production and consumption in the country–currently favouring State-owned utilities over private producers–to allow for emerging paradigms (like *prosumerism*) and best practices (like smart grids, virtual power plants and demand management schemes) to be implemented while fostering innovation for future adjustment and improvement.

Specific projects–each with its own needs regarding market conditions, governance, and finance–span across the whole electricity system, and they must be implemented simultaneously to enable the rapid shift required by Mexico's climate goals:

— **Renewable electricity generation.** The federal government must allocate significantly more capital than currently planned or available for renewable energy generation, preferably in partnership with private and international investors to achieve the necessary scale within net-zero compatible timeframes. This increase in investment should not raise repayment costs to a level that undermines public finances or limits other essential development spending. Mexican electricity market conditions and regulation must ensure the business case of renewable against fossil generation by creating the conditions for a return to investors. International cooperation will be crucial to ensuring renewable generation can be funded at the scale and speed required.

— **Electrical transmission network.** Mexico's electric grid is already struggling due to saturated transmission infrastructure. Decarbonization requires the federal government to allocate significantly more capital than currently planned for transmission, which will likely remain on the government's books. Because transmission is a public good that enables economic development and private investment in generation and storage, its financial returns may be indirect or long-term. Increased investment in this area must not raise the cost of repayments to the detriment of public finances or the ability to make other essential investments for national development. New financing mechanisms, competitive infrastructure procurement and green bonds, could help mobilize additional capital while ensuring clear rules and predictable revenues for grid services.

— **Distributed Generation (DG).** DG in Mexico presents a positive business case across many States, but rollout is hindered largely by access to capital for households and small businesses, as well as the current electricity market rules that do not allow end users to commercialize the electricity they produce and that subsidize residential electricity use. Additional to capital, capacity building support will be useful to revamp current paradigms towards the best practices and technologies.

- Mexican energy businesses and financial services companies can create investment portfolios aggregating small-scale projects, improving their ability to attract financing.
- In parallel, the Mexican Ministry of Finance (SHCP) must agree to share cashflow with these companies, based on a fraction of subsidies saved by reducing residential electricity demand from the grid.
- Centralized utility CFE must enable local and province-level financing initiatives, including regional funds and risk-pooling, to stimulate the economic activity of DG rollout and the positive impacts to users.
- CFE and grid regulators must transition to a new operating paradigm to enable a future market where DG goes beyond bringing savings at the local level to contributing to renewable electricity generation and grid balance at the national scale. This will entail an upgrade of the distribution grid and metering infrastructure for which additional international finance support might be relevant.

— **Innovative businesses and business models.** The roll-out of renewable energy should kick off new business opportunities such as in green hydrogen, synthetic fuels, and different types of energy management and storage strategies. Developing these industries will require venture and risk capital, as well as capacity building, technology innovation and implementation, and international trade will be needed to increase the viability of the new low-carbon energy industries.

- Mexico could adopt a programmatic innovation framework where a variety of international parties like expert organizations, academia, energy regulators, and businesses could network to motivate, plan and monitor innovation in technology, capacities and regulation.
- Dedicated funding for new ventures and new business models must be scaled-up in-country, backed by international cooperation.
- Collaborative governance structures should be established between Mexican officials, international cooperation, and foreign investors

The scale of finance required presents the largest challenge to the transition.

According to the IPCC (Clarke *et al.*, 2022), global climate finance flows remain far below needs, particularly for developing countries, where it must increase by a factor of 4 to 7 to meet Paris goals. In the electricity sector underinvestment is compounded by a climate investment trap: higher financing costs, perceived macro and policy risks, and limited institutional capacity discourage capital inflows and delay clean infrastructure, reinforcing fossil dependence. This is consistent with the challenges faced by Mexico, where the transition to renewables must occur under constrained fiscal space and limited domestic capital availability.

Mexico's net-zero scenarios require approximately tripling the capital investment of scenarios representing prior NDC commitments–a significant challenge. In the long term, the high-renewables scenario can yield important economic advantages as the consumption of fuels is reduced and recurring fuel costs plummet. Despite the very large scale of investment needed, over years of operation these fuel savings can pay back the capital expenses incurred during installation. In fact, not switching to a renewables-based electric power on a timely manner delays these savings from materializing creating large opportunity costs (INECC, 2024).

International cooperation must leverage this programmatic approach to ensure lower capital costs and greater capital availability for the Mexican electricity system.

Mexico and other developing countries will need more, and less costly, international capital to help them transition to low-carbon power grids.

The country's main needs can all benefit from tailored international cooperation combining concessional finance, guarantees, and technology partnerships supporting well designed portfolios pursuing mixed financial, economic, enabling infrastructure, environmental, and social objectives.

The large additional investment required to reach a high-renewables scenario means Mexico will not have the fiscal space to fund the transition without support. The IPCC outlines several priority levers to align financial flows with long-term goals, which can be directly operationalized through specific cooperation instruments. This points to the need for international cooperation to provide both cost of capital reduction and increased capital availability.

Concrete international cooperation interventions can align with and support Mexico's programmatic rollout and scaling up of renewable generation and supporting investments.

The measures presented above translate the IPCC's global guidance into a practical agenda for Mexico and Latin America combining domestic reform with tailored international finance packages. This integrated approach can lower investment risks, attract private participation at scale, and accelerate the transition to a resilient, low-carbon power grid. In addition, concrete support for capacity building, market rules, technology rollout, and new business can be tailored to Mexico's programmatic actions describe previously:

— **Renewable electricity generation.** International financial support must increase volumes of capital available for energy financing in global capital markets. MDB and bilateral donors can provide concessional finance and risk reduction instruments, whose impact can be leveraged up by underpinning agreements with national and international private investors that are supported by electricity tariff payments and fuel savings over the long term, allowing the economic benefits of renewables to accrue to investors while not exposing them to an increased country risk premium due to the volume of financing. In addition, Mexico's renewable generation can be partially funded by green bonds, issued either by Mexico or by credible investment vehicles who then commit them to Mexico.

— **Electrical transmission network.** As Mexico's grid prepares for a high share of renewable generation, system planning and management would benefit from capacity building support from experts in countries that are further along this journey. In addition, financial support will be needed, with similar international cooperation interventions to those described above for renewable generation. However, the nature of transmission as enabling infrastructure makes the ability to recover the investment highly dependent on policy rules, and payback timelines may be longer in order to ensure viable generation and manageable tariffs. Green bonds linked to long-term infrastructure development could be particularly well suited to this application.

— **Distributed Generation (DG).** International capacity building support can play a role in enabling CFE and local network managers to adopt policies and pricing strategies that align DG operation with grid needs. International and national investment in technology support can unlock business opportunities for production, assembly and installation of panel components and supporting electrical equipment. Financial support will vary by user, with subsidized electricity users being a priority since their uptake of DG cuts Mexico's subsidy bill, strengthening national finances. This support could go straight to the Mexican government who could then co-finance installation across subsidized households and service the debt over a tenor that makes this service lower than the subsidy savings. For businesses seeking to install DG, development bank support from NAFIN could be boosted by international funds, and distributed via commercial banks. Development bank funding could be channelled in a similar manner to companies working to implement different aspects of DG along the value chain and across geographic regions and customer groups.

— **Innovative businesses and business models.** Supporting new businesses and business models can benefit from expertise, funding, and favourable trade conditions for new companies, products and services. This will require significant international support across all of these to rapidly scale up institutional capabilities to drive the electricity system transition and economic growth at the same time.

- International financial support should include seed (grant) funding and dedicated guarantees for new businesses (such aggregators of DG demand in subsidized residential uses to kick-start the market), staged grants for innovative businesses as they prove the functionality of their product or service and progress to make it commercially viable; access to favourable credit as companies aim to scale up operations.
- International capacity building support should extend to Mexico's institutional capacities to support innovation as well as to those enterprises that aim to build new businesses in energy storage, energy management, renewable generation, and other associated services.
- International technology and trade support should both help Mexican institutions shape market conditions to favour innovation and provide market conditions directly, for example with tariff support to enable Mexican innovative businesses to export regionally and globally.

The Mexico case illustrates the potential for regional programmatic cooperation.
Designing portfolios with mixed economic, enabling infrastructure, and environmental and social objectives is not only useful as a planning tool for countries to gain full agency over their respective transitions towards green and just economies, but it can also provide insights to structure international collaboration efforts.

A further regional dimension could be pursued with Latin American countries building these joint programmatic visions and portfolios to attract funding institutions under collaboration packages like those described above. By pooling efforts, countries can address common challenges and investment needs more effectively. Collaborative governance structures can provide a versatile framework for state-of-the-art instruments like joint procurement platforms for high-tech grid equipment, co-financing of infrastructure or interconnection projects, shared guarantees or regional insurance mechanisms for cross-border public-private partnerships, results-based finance or pay-for-performance tied to grid reliability or flexibility improvements, regional thematic bonds linked to innovation, capacity building, or energy storage.

Regional collaboration also helps reduce risks and costs, as mechanisms like risk-pooling, regional insurance, green bond labels, and standardized disclosures can deepen investor confidence and expand market access. Joint procurement further lowers the unit cost of advanced grid technologies. Collectively, these measures put into practice the IPCC's alignment levers in a regional context: linking risk reduction, transparency, and financial innovation to accelerate the clean energy transition across Latin America.

2.2. Mexico case study on shifting to electric public transport

Decarbonization of the transport sector is essential to achieve global climate goals, and can address other pressing problems at the local level.

The transport sector is one of the largest GHG sources and a cornerstone of the current dependence on fossil fuels, with car-centred cities harming public health and fragmenting communities and neighbourhoods.
In 2019, transport accounted for 23% of global energy-related CO_2 emissions, with 70% of those generated by road vehicles. Oil derivatives such as gasoline, diesel, jet fuel and residual fuel

oil are the prevalent energy source for transportation systems globally. In countries with car-centred cities like Mexico and others in Latin America transportation can represent huge costs associated to the imports of these fuels to feed private car fleets. For example, in 2023 Mexico imported 66% of the gasoline and 63% of the diesel consumed in the country (totalling 1,668 PJ and 928 PJ, respectively) (SENER, 2025).

Additional to greenhouse gas emissions, the intensive use of cars in cities has been singled out as the main cause of a variety of problems, like road accidents (Mohammed *et al.*, 2019), air and noise pollution (Chamberlain *et al.*, 2023), congestion (Rivas *et al.*, 2019), environmental degradation, and the lock-in of car-centred urban design that impact the daily life of the population, especially those who are more vulnerable (Miner *et al.*, 2024).

Decarbonization of cities will require systemic change in urban mobility systems. This entails reducing car use and shifting to electric public transit to drive energy efficiency, reduce environmental impacts, and revitalize neighbourhoods.

Given the large and growing demand for mobility of both people and goods, switching technology to electric vehicles and trucks will not suffice to achieve ambitious emissions reductions targets in time. Demand management solutions will also be needed in combination with these new technologies. (Clarke *et al.*, 2022)

Shifting urban transport systems away from cars to electric public transport (EPT)–especially that confined to specific lanes and spaces like bus rapid transit (BRT), trams and trains–and non-motorized transport like cycling and walking dramatically decreases road accidents, pollution, GHG emissions, and noise, as well as increasing energy efficiency by reducing energy use per passenger-kilometre. From an urban structure perspective, reducing the role of cars and the road space dedicated to them makes neighbourhoods more accessible to pedestrians, allowing for an urban design centred on the human scale rather than on the speed of cars.

Deploying EPT at scale requires harmonized technical standards, bulk procurement, long-term financing, and shared research and development mechanisms achievable only through coordinated regional cooperation.

Changing transport systems faces important barriers but also presents significant opportunities through a programmatic vision for systemic change.

Decarbonizing urban passenger transportation will require a new vision of mobility–redefining the conditions under which travel demand is met–as well as widespread technology changes.

The technologies needed to decarbonize passenger transport are already commercially available, assuming zero-carbon electricity is available: electric trains, trams, buses, cars, and regular bicycles. It's the urban space and infrastructure dedicated to each of these modes and how well they integrate amongst themselves that makes the difference to users (Energy Innovation, 2014).

Transforming the transport sector is then, as much about understanding and reshaping the drivers of mobility demand as it is about technology choices. Cities needs to articulate long-term visions for mobility that integrate changes in urban form, infrastructure investment, transport fleets, digital systems, and travel behaviours. Such visions provide the foundation for coordinated, programmatic action and for aligning international cooperation with locally defined transition pathways.

The "Avoid, Shift, Improve" framework (Dalkmann *et al.*, 2007) provides a coherent structure for this vision, linking demand management, modal change, and technological improvement within a single pathway. Applied programmatically it can guide a long-term view of shifts in urban structure to avoid the systemic challenges faced by LAC cities (especially megacities) today by helping alignment of public policy, investment, and institutional reform.

— **Avoid** focuses on limiting growth in transport demand through more compact and mixed-use urban development, decentralization of services and economic activity, and remote or hybrid work where feasible.

— **Shift** means meeting mobility needs through public and non-motorized transport rather than private vehicles. In the near term, this includes electrifying existing bus fleets and expanding BRT, while identifying corridors where longer-term rail investment is required.

— **Improve** focuses on the environmental and energy performance of all transport modes, particularly through electrification and efficiency gains in public transport.

Delivering this vision at scale requires coordination on standards, financing, operations, and learning, and it commonly exceeds the capacity of individual cities. Regional cooperation can play a critical role by reducing costs and risks, joining up problem solving capabilities, and accelerating implementation across cities.

Most LAC cities have inadequate public transport, requiring a dramatic increase in fleets and infrastructure to reduce reliance on private vehicles.

Today, most cities in Latin America rely on private lightweight vehicles to satisfy much of mobility demand, with public transportation primarily serving the poorest sectors of society. Consequently, the transition to sustainable transportation systems will require many cities to scale up their supply of public transportation infrastructure, fleets and operators.

As an example, Mexico City is home to 9.2 million inhabitants and has a fleet of only 1,360 regular buses, 425 electric trolley (catenary) buses, 872 BRT buses, and 394 trains (CDMX, 2025). Looking to 2050, a net zero scenario would require over 10 times more busses (all electrical), while a BAU scenario would require more than doubling the current car fleet which would lead to unmanageable congestion and critically insufficient parking space. (Own analysis with data from (Buira, 2021)). Achieving such a notable shift in transport fleet will require careful planning and significant additional investment in transport systems than that traditionally made by cities in LAC.

Electric busses and BRT can kick-start the transition, while building towards a longer-term rollout of rail options.

The electrification of busses and the extension of (electric) BRT lines can help kick-start the electrification of mass transit in LAC cities while aiming to drive economic activity within the region. In the short term, current bus services can be decarbonized directly by switching from diesel to electricity as the energy source, which can in turn be achieved with new electric busses or by retrofitting electric drivetrains on to the current fleets. This second approach could reduce the need to import new electric busses in the short term, hence reducing the cost of electrification, while creating local jobs and expertise with dedicated retrofitting programmes. While battery electric busses will require some infrastructure for charging, this should not represent a major cost nor space requirement in comparison to other public transport investments.

In the medium term, the development of new bus and BRT routes can be instrumental in persuading citizens used to driving private vehicles to make the switch to public transport, especially in corridors where peak-hour transit times can be much shorter than the private vehicle alternative. In the longer term, the ongoing uptake of electric busses will prove a significant market for national/regional manufacturing and supply chains.

Despite these advantages, it is important to recall that busses do not always represent the best public transport solution, particularly for corridors with very high peak demand. This is because rail-based alternatives, such as trams, trains, and metro systems, can move far more passengers per unit and can operate at very high frequencies at peak times. Deploying BRT in corridors where rail would be a more appropriate option can create infrastructure and institutional lock-in, divert capital from rail investments, and undermine public confidence if capacity supplied is insufficient from the first day of operation. Hence, the roll-out of electric busses must be pursued within the context of a broader urban strategy for sustainable transport.

Aggregate demand from Latin American countries can justify investments in local manufacturing capabilities to capture the majority of economic activity, as opposed to importing vehicles.

The incremental investment needed to produce and deploy electric transportation fleets and infrastructure will represent an effort beyond the present capacities of most municipal, provincial and regional governments. This would justify channelling public resources and attracting private capital into lowering the perceived risk through predictable procurement pipelines and robust project preparation.

This large scale of investment presents an opportunity for regional cooperation between LAC cities, which can create an aggregate demand across hundreds of millions of citizens. Coordinating multiple megacities, dozens of large cities (over 1 million inhabitants), and numerous medium and small cities, can create market conditions robust enough to justify investment of public resources and private capital, while also lowering the perceived risk of new manufacturing capacity through predictable procurement pipelines and robust project preparation.

These new economic activities can help reduce the need for fossil fuel imports in countries which do not produce them, and substitute exports in countries where currently they are important contributors to domestic economic growth, effectively helping to break the techno-economic lock-in associated with fossil-fuel-dependent mobility and growth models.

International regional (South-South) cooperation between LAC countries can support both aggregate demand and strengthen supply chains for decarbonized transport technologies (e.g. electric busses).

Regional (South-South) international collaboration can structure aggregate demand, paving the way for regional supply chains to benefit from the transition.

Cooperation between LAC cities can lead to important aggregate demand for electrical transportation technologies, thereby creating market conditions that support the regional value chains for new transport technologies. Collaborative governance and agreements on common definitions, standards, and commercial terms will be crucial to stimulate new regional supply by ensuring a predictable demand throughout the payback period of investments in the manufacturing capabilities that will be required.

Collaborative governance and institutional arrangements will also be necessary to agree the location and exact nature of activity on the supply side, balancing technical and economic considerations with the need to balance benefits across participants. Political and economic agreement on the role that city and central governments, private companies and private investors will have in the new industries will be key.

Shared mobility challenges also create a strong basis for joint solutions: standardized planning tools, regional training programs, and cross-city knowledge exchanges can accelerate the transition. South-South international collaboration can help developing countries to establish the new industries needed at a regional level reducing their technological dependence on developed countries.

Many LAC cities have implemented BRT systems in the last decade, with the necessary regulatory capabilities to operate them effectively within their urban and social contexts. Their existing technical and institutional capacities can constitute a regional confederation of stakeholders to guide the aggregation of electric bus demand under a long-term international collaboration scheme, as well creating a community of practice for the whole region where innovation and best practices can spread rapidly.

This collaboration can accelerate adaption to sustainable mobility requirements. On the one hand, route planning, fleet and service management must be modernized, regardless of the vehicle fleet's powertrain technology. Equally important is the shared learning that can speed the adoption of different solutions, such as dedicated lanes, integrated payment systems, high frequency services during peak hours, and comfortable and safe vehicles. A technological transformation plan should inform the design of routes, lanes, and infrastructure to ensure compatibility with future options, such as establishing capacity for charging stations for battery-powered or hydrogen buses, overhead power lines, or the evolution to more efficient systems like trams and trains.

Regional (South-South) international collaboration can kick-start regional supply chains to satisfy regional aggregate demand.

The LAC region already has important bus manufacturing capabilities, with related industries and value chains, both for new-builds and for the maintenance of fleets that might have been originally imported. The electrification by retrofitting of existing diesel-based buses, the modification of currently produced models to include electrical drivetrains, and the design and manufacture of fully electric vehicles form a continuum of activity, of which different parts will be most relevant to different countries. However, in each of these, there are important opportunities for industrial activity that can be satisfied by LAC supply chains.

Leading manufacturers and national champions should be invited to form a task force to flesh out the opportunity over the short, medium, and long term, particularly in terms of developing a competitive advantage with respect to importing busses and/or components from other regions. This work should assess the competitive advantages that different LAC countries may have in e.g. vehicle assembly, parts manufacturing, electrical and electronic components, etc. to propose options for configuration of a regional supply chain. The national development banks and industrial policy agencies of participating countries should also be involved to ensure a balanced distribution of work that can help widespread development across the region while providing cost-effective products to cities.

The development and agreement of concrete plans of the necessary scale and complexity to promote electrification of transportation would lend credibility to the region in the various processes of seeking support, financing, and trade agreements with those countries and suppliers that will need to play their own role in strengthening the electric vehicle value chains in LAC.

These concrete plans would also strengthen the region's position when seeking concessional finance, guarantees, and partnerships with international donors, development finance institutions, and global suppliers. Similarly, a shared, transit-based electromobility vision across countries can improve policy continuity across electoral cycles and identify priority areas for operational and regulatory alignment, accelerating implementation at regional scale.

Regional international (South-South) cooperation will require closer alignment and coordination across demand and supply.

Developing electric public transit in LAC will encompass a strategy with various milestones in the short, medium, and long term, considering existing capabilities and opportunities of potential partners. Within this context, participating LAC partner countries should work to foster innovation ecosystems, management capabilities (in both the public and private sectors), and widespread awareness of the opportunities available within a sustainable development model.

Regional cooperation on electric buses will require both a coordinating institutional framework and an inclusive community of practice. The coordinating framework should support harmonized technical standards, pooled procurement, and interfaces with development finance, while the community of practice should enable training, peer exchange, and rapid diffusion of operational lessons.

Alignment between countries' climate goals and the policies relevant to achieving them, in the long, medium, and short term, can also facilitate collaboration by presenting common elements for all countries. Specific examples to consider include:

— **Harmonization of policies.** Alignment of the objectives in countries' NDCs, LT-LEDS, and other environmental, energy, and economic policies would help set long-term objectives to align decision-making processes in the public and private sectors.
  - Partnerships at the city level–not usually included in the UNFCCC architecture–would help advance and inform formal agreements between countries while these take shape.
  - Regulatory harmonization to facilitate trade, investment, and the movement of people between countries advancing a shared mission of sustainable development.
  - Harmonization of tax policies and public prices can help align public prices and incentives with climate goals.

— **Strengthening public sector capacities at the national and subnational levels** will facilitate economic transformation processes through prioritizing sustainable development, agile management of required concrete changes, and the strategic use of public procurement.

— **Fostering national innovation ecosystems** with processes that foster regional collaboration, including within academia/universities and private companies.
  - Establishing a forum or community of practice where experts can conduct novel, open and exploratory analyses and dialogue on generating potential joint strategies for collaboration is a crucial first step.

— **Development of international climate finance campaigns** will prove useful to expand the new electric public transit technologies and productive chains beyond the local and regional context into a continental and global scales.

— **Socioeconomic transition approaches to prevent and reduce inequality** while promoting climate objectives are important to attain a just transition that can tackle development objectives additional to climate change mitigation. They can also help develop an attractive environment for other partners to join in the collaboration platforms and programmes.

International (North-South) cooperation should both support and adapt to the programmatic perspective, working to enable both supply and demand actions through a range of coordinated interventions, including the need to fund additional investment.

International partners can provide capacity building support both in-country and at regional level to help cities coordinate to aggregate demand, learn best practices, integrate supply chains and configure investments and operations. Supply-side actions could also benefit from capacity building support, as well as technology and implementation support, to help investors and companies identify and invest in concrete areas of opportunity that will grow local value. International cooperation should also help establish links with global companies that manufacture electrical public transport will help build partnerships to ensure cost-effectiveness even while retaining most of the economic activity in LAC.

To further define the specific support required, a group of relevant donor institutions and LAC organizations (from cities, industry, civil society and local and national governments) should engage in a process to outline how such collaboration could take place. In addition, this support must be provided in coordination with financial support for regional cooperation on electrical public transport, which will be varied along the different stages of programmatic rollout to ensure its economic viability. Grant and concessional funding will play a crucial role in the early stages.

Strong institutional capabilities that are trusted thanks to their technical quality and fair representation of diverse stakeholders will be necessary to provide credible governance for this regional collaboration. Dedicated funding to build up, train, and maintain such capabilities will be important, with international cooperation providing funds to be managed by the governance arrangements, under full transparency.

International cooperation must also work to ensure that funds are available at sufficient scale to enable the first implementation steps outlined by the regional cooperation efforts, to take hold. In the medium to long term, the transition will require significant increased investment in urban infrastructure and vehicle fleet compared to traditional investments in transportation in LAC. International cooperation can support this scale-up by enabling access to long-tenor, affordable financing for both LAC cities and for companies investing in EPT value chains, strengthening domestic financial intermediation through national development banks, and improving the creditworthiness and planning capacity of national and subnational governments so that ambitious regional plans can be implemented at pace.

2.3. Mexico case study on producing Green Iron and Steel with Hydrogen

Iron and Steel–traditionally considered "hard-to-abate" industries–can be decarbonized using Green Hydrogen.

Iron and steel represent a global industry which is foundational to economic wellbeing and accounts for 7% of global emissions and has traditionally been considered "hard to abate".

The iron and steel industries are responsible for 7% of global emissions in 2024, (Martin, 2025), (World Steel Association, 2024). more than the amount generated by all road freight transport worldwide. Emissions derive not only from the intense energy use required to extract metal from the mineral ore, but also from the chemical reaction involved in this process. However, technological advances over the past decade have demonstrated that low-emissions alternatives are available for every step in the process.

Steel is a versatile material with many uses across the global economy. The largest end-use sector for steel is construction of buildings and infrastructure. However, it is also found across a broad range of applications within manufactured products including machinery, tools, domestic appliances, automotive, and many others. This ubiquity and essential character of steel have led to a widely distributed industry around the world, with many middle-income countries boasting significant production assets, and developed countries, striving to retain capacity and jobs even when their production costs make them less competitive on the global market.

For developing countries, increasing the stock of steel per capita will be necessary to build up the infrastructure and industry that they aspire to. Therefore, global production volumes must increase, meaning the new low-emissions production processes that must be rapidly rolled out across the industry.

Switching to a Hydrogen Direct Reduction technology can practically eliminate on-site emissions from iron and primary steel.

Iron and steelmaking involves two main stages. In the first, iron is extracted from iron ore. Traditionally, this is done using coal in blast furnaces, while more modern Direct Reduced Iron (DRI) processes use natural gas and have significantly lower emissions. The leading option for fully decarbonizing this stage is Hydrogen Direct Reduction of Iron (HDRI), which uses hydrogen instead of fossil fuels and produces water rather than CO_2 as the main by-product.

In the second stage, the iron is transformed into steel. This can be done using fossil-fuel-based Basic Oxygen Furnaces (BOF) or electric arc furnaces (EAF). EAF technology can operate with very low or zero emissions when powered by clean electricity. Steel can also be produced directly from recycled scrap, avoiding the ironmaking stage altogether and generally resulting in a much lower GHG footprint.

Mexico's current steel-making capacity and abundant renewable resource make it a potentially competitive producer of Green Iron and Steel.

Mexico's iron and steel industry is modern, globally connected, and well configured to transition to HDRI.

Mexico's steel industry produced approximately 14 million tons of steel in 2024, making it the 15th largest producer worldwide (World Steel Association, 2025)., with a broad range of activities from mining and smelting to bulk and specialized steel making for automotive and aeronautical applications, as well as extensive use of steel in the construction and manufacturing sectors. Mexico's steel market is open and dynamic, with high levels of both imports and exports, and both national and international ownership of diverse assets.

Mexico's production fleet is modern and efficient (CANACERO, 2025), with average energy use and CO_2 emissions per ton at 48% below world average values (11 GJ *vs* 21 GJ, and 1.1 *vs* 1.9 tCO_2 respectively). Over 90% of national production used the cleaner gas-based NGDRI-EAF technology pathway, while the coal-powered BF-BOF technology route is used for 70% of global production.

The high penetration of NGDRI gives confidence that Mexican iron ore is rich enough in iron content to support HDRI, and that the technical processes and staff currently operating in Mexico would be more familiar with the basic operating logic and energy and material flows of HDRI.

Since Mexican steelmaking is dominated by EAF technology, which is powered by electricity and hence has zero on-site emissions, this second stage can be decarbonized simply by providing zero emissions electricity to the EAF. Furthermore, secondary steel already accounts for 54% of steel production in Mexico (CANACERO, 2025), almost entirely produced with EAF technology and hence technologically straightforward to decarbonize.

Mexico's abundant renewable resource can underpin a competitive green H2 industry through the rapid deployment of renewable generation and a supporting grid.

Mexico's abundant renewable resource is an advantage in terms of international competitiveness to manufacture green iron and steel. For secondary steel, an increase in renewable electricity can rapidly decarbonize production, while improved recycling and scrap handling policies can increase volumes and reduce feedstock costs. On the other hand, decarbonization of ironmaking and primary steelmaking will require a transition to HDRI technology, which in turn will need a reliable supply of green H2 (GH2) at viable prices over many years.

Central to energy system scenarios for Mexico's decarbonization is the ability to manage a robust and reliable electrical grid as a greater share of the power becomes intermittent. The rollout of GH2 capacity can play an important role in balancing such a network, since GH2 generation and management can add flexibility to the network by using excess peaks in generation (potentially at lower or even negative electricity prices), as well as providing energy storage. This scope for synergy between GH2 capacity rollout and a broader energy system decarbonization and indeed potential decarbonization of industry and transportation suggests investors interested in using H2 for HDRI may find co-investors, sharing financing costs and diversifying project risk.

Rolling out Green Iron and Steel requires a coordinated approach to Green Hydrogen as part of a country-wide decarbonization plan.

The switch from natural gas-fuelled DRI to HDRI is technologically viable today

Iron-making furnaces typically require a major refurbishment (or "relining") every 15 years, which takes them out of operation for 6 to 12 months. The switch to HDRI technology could be implemented by leading Mexican NGDRI facilities during the next re-lining with relatively little additional disruption, albeit at an additional cost and potentially with a longer downtime.

However, investors must consider both costs of technology implementation and risk of technology underperformance or failure before investing in HDRI. Support from national or subnational government, in combination with favourable/grant funding from international cooperation should be made available to the first plant(s) to decide to switch to HDRI, reducing the impact of the incremental cost from the new technology or the extended downtime, and incentivizing investment to create a precedent for the national sector to learn from.

With regards to technology risk, the industry already has high confidence in the viability of HDRI, with a full-scale integrated project (including production of GH2, green iron, and green steel) under construction in Boden, Sweden (Stegra, 2026). In addition, recent technological developments include DRI furnace technologies that can work with a range of input gasses, ranging from 100% methane to 100% hydrogen or any mix of the two, with minor modifications (GMK, 2025).

A Mexican facility currently using NGDRI could install such a technology at its next re-lining, thus enabling green iron and steel production while hedging the risk around of GH2 availability. With over 10 modern NGDRI facilities in operation in Mexico, it is likely that at least one or two will stop operations for re-lining during the present presidential administration. Introducing HDRI-compatible technology will create an option to start producing green iron and steel should the right market conditions become available at any point over the next 15 years. Therefore, if the right support is in place to mitigate the additional costs of installing HDRI, companies could be open to implement this technology switch.

In addition, in-country trade support to provide a "green premium" for GIS will be needed to overcome the high GH2 production costs and thereby stimulate investment in HDRI.

The availability of sufficient GH2 at a viable price presents a greater barrier to HDRI uptake than the cost or risk of the technology itself. This was illustrated during 2025, when ArcelorMittal cancelled an a planned HDRI project in Germany due to concerns about GH2 supply costs, despite the 1.3bn Euro grant previously agreed (Industry Linqs, 2025).

Mexico's abundant solar energy suggests it could create competitive GH2 from renewable energy. However, the process to generate GH2 from water using electricity requires the use of electrolysers, which represent an important capital investment, meaning that using GH2 will remain more expensive than using natural gas for some time.

These challenges suggest how Mexico's government might consider options to support the development of a HDRI plant in Mexico. While direct subsidies for construction are possible, an alternative could be to provide revenue support through a revenue-neutral scheme which subsidises the production of a first HDRI plant to an agreed amount per ton, while distributing the cost of this revenue support across a tax on all non-HDRI production in Mexico. Such a "subsidy plus recharge" scheme could apply only to production consumed in Mexico, thereby not impacting international competitiveness, while representing a minor increase (likely under 1%) in the cost of finished goods to pay for the policy (as initial GIS volumes would be limited to those of the first plant to take up HDRI) (Morrisroe *et al.*, 2025).

An in-country coordinated approach across sectors–such as "GH2 hubs"–is needed to ensure a reliable supply of GH2 at viable price and volume.

The cost of setting up a GH2 plant makes it is unlikely that a Mexican steel company will singlehandedly commission a GH2 production facility as part of their own product development. However, cooperation between likely users of GH2 could result in the creation of GH2 "hubs" or "ecosystems" where costs and risks are shared among multiple beneficiaries, and enabling the production of a decarbonized fuel should motivate support from subnational or national government and international support.

Such GH2 ecosystems can be important enabler of a GH2 rollout (Bouacida *et al.*, 2022) leveraging existing opportunities which can be easily linked to other medium and long-term opportunities across different sectors to diversify risk and accelerate growth. The IEA has identified four high-level value-chains that could boost GH2 production and use, including industrial ports or transport users, allowing infrastructure, supply and risks to be shared (IEA, 2020). Such "green hydrogen clusters" are already receiving support within the EU. Thus, including Mexico's development of green iron and steel as a component of a national green H2 economy can both share costs and reduce the risks for iron and steel investors and broaden the potential opportunities for the green H2 economy in which Mexico has a competitive advantage. It is important to note that Mexico does not currently have a green H2 strategy, which places it behind many Latin American peers, although recent announcements suggest the current government will develop one.

International cooperation can provide an offtake price for first-wave GIS projects, by adjusting the international trade regime to favour an efficient transition of the industry.

Developed and developing countries can establish programmatic partnerships across the iron and steel value chain to support decarbonization of iron while recognizing the need to retain steelmaking activity across different countries.

A global pathway towards zero-emissions steel will require a rapid technology shift. As both developed and developing countries map out their strategies, they must consider their ability to access high-grade ore and GH2 at low cost, potentially exploring partnerships or other strategies to address gaps.

The foundational character of the iron and steel industry means that, beside its economic importance, it often has high political visibility as a bellwether of a country's industrial and manufacturing significance. At the same time, the crucial dependence of HDRI on competitive GH2 production means developing countries may have a competitive advantage over those in the Global North. Therefore, a shift in iron and steelmaking activities between countries will be needed but must be treated with due consideration of the views of a broad range of stakeholders. It should also be noted that today's steel market already suffers from production overcapacity of primary steel, meaning that some facilities currently in operation will go out of business regardless of the need for a low-carbon transition.

Bilateral partnerships may present a form of international cooperation that enables developed countries to maintain a competitive green steel industry while supporting the development of green iron production in developing countries. A potential scheme (Trollip *et al.*, 2022) involves establishing HDRI facilities in developing countries with competitive GH2 potential and high-grade ore, in order to produce green iron to serve as a feedstock for steelmaking. The developed country partner agrees to purchase the it at a price that enables the HDRI facility to operate profitably, substituting local ironmaking with green iron imports. In this way, the developed country can retain most of the value-added activity in the value chain, and deliver low-carbon products to its end-markets, stimulating investments in new HDRI primary capacity in the developing country, where GIS demand is expected to grow more in the longer term, creating jobs and economic activity and kick-starting the local GH2 and green iron and steel (GIS) industries.

The highly traded nature steel means that international trade support for primary GIS rollout will be needed to displace traditional steel over the coming decades.

Steel is a highly traded commodity, with many countries engaging in significant imports and exports as different companies source or place their products on international markets. In addition, global over-capacity is leading to a "race to the bottom" on price which limits the ability of producers to add a premium. Tariffs form another important component of international markets, as these are set by many countries primarily to protect national production from global overcapacity. In this context, it is difficult for countries to implement policies that guarantee a price premium to producers of green primary steel.

However, manufacturers need to ensure they can pass on the increased production cost from using GH2 instead of fossil fuels when they adopt HDRI. While specific bilateral cooperation may lead to offtake agreements in some instances, this is unlikely to provide a scalable solution to accelerate global uptake of GIS production. Therefore, changes to global trading rules should be pursued to provide primary GIS producers with a premium, while managing the diverse interests of multiple stakeholders.

A concrete proposal (Morrisroe *et al.*, 2025) involves a multi-step process, offering stimuli at different stages of evolution of HDRI iron and steel production. A first step would involve the exemption of import tariffs for green iron or primary steel. Such a policy would provide a notable premium to GIS makers, encouraging investment in GIS facilities and GH2 production, and thus kick-starting the shift in those developing countries best suited to lead it. It would also have limited impact on the importing country's fiscal revenue or national steel industry due to the low volumes of GIS present at the start. As costs come down and local steelmakers and manufacturers understand how imported HDRI can be play a role within their portfolio, green HDRI will become more attractive for investors, while the model of importing some fraction of green iron to sustain a thriving local steel and manufacturing industry on its way to decarbonization will likely become more acceptable.

National and international trade support for GIS must work in conjunction to accelerate rollout, pointing to the need for collaborative governance approaches to guide international partnerships.

The challenge of kicking off the technology transition to HDRI iron and primary steelmaking can be tackled by a package of policies that can provide first movers with a competitive advantage while not destabilizing current markets or creating large additional costs for governments or consumers. Such a result can be achieved by combining the subsidy plus recharge policy at the national level with tariff exemptions at the international level.

This exemplifies the changes international cooperation must undergo in order to deliver on the GST result This represents a step-change in the implementation of international cooperation and will likely require new institutional frameworks, based on the guiding principles of the Paris Agreement, the need to achieve rapid transformational change, and the construction of a joint programmatic vision for implementation.

International cooperation can also support GH2 hubs in developing countries, with technology support, capacity building, and financial support.

Developing countries must establish their own approach to developing GH2 hubs, since these will not be suitable for all countries, and international cooperation can play an important role.

Investment in renewable electricity supply, electrolysers, and transport / storage infrastructure will benefit from international expertise and potentially technology support to ensure leading technologies are available to developing countries, as well as to explore the potential for in-country economic activity in technology production or assembly. The scale of investment committed to a scheme whose profitability will require favourable international trade agreements will further benefit from financial support to reduce the risk profile and to ensure sufficient capital is available. As an initial investment gets underway and achieves operational success the perceived market risk of follow-on investments can be expected to drop significantly.

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A programmatic approach to enhance international climate cooperation: lessons from three system transformation studies in Mexico

Daniel Buira, Jordi Tovilla, Thalia Hernández (Tempus Analítica),
with contributions from Ana Pérez Català & Marta Torres Gunfaus (IDDRI)

Buira, D., Tovilla, J., Hernández, T. (Tempus Analítica), with contributions from A. Pérez Català & M. Torres Gunfaus (IDDRI), (2026). A programmatic approach to enhance international climate cooperation: lessons from three system transformation studies in Mexico. *Study* N°0326, IDDRI, Paris, France.

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CONTACT
anna.perezcatala@iddri.org

Institut du développement durable et des relations internationales 41, rue du Four – 75006 Paris – France