9. Solar PV distributed generation in Mexico

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Over the past decade, Mexico has implemented several policies to reduce greenhouse gas emissions from the energy sector while promoting sustainable environmental, social and economic development. During this period, Mexico's energy sector has seen a 50% increase in installed electricity generation capacity, driven largely by significant growth in wind and solar PV, which now account for around 20% of total installed capacity.

This case study examines how policies are encouraging innovation in the deployment of distributed generation from clean energy sources, particularly solar PV, and assesses the extent to which this has actually led to increased value added in the supply chain. Policies for distributed generation successfully drove a significant increase in installed distributed solar PV capacity in the last three years, which has spurred the growth of numerous small distribution companies across the country focused on installation and maintenance. This expansion of active solar PV companies throughout the country and demand for large solar PV power plants did not translate into significant investment in domestic manufacturing capacity. More recently, however, Mexico's world-renowned manufacturing expertise, combined with its close access to the large US market, where government measures seeks to reduce reliance on solar PV imports from China and Southeast Asia, has supported an increase in solar PV module manufacturing capacity in Mexico that can meet all domestic demand and produce products for export. Existing manufacturing capabilities and Mexico’s skilled workforce could provide a strong foundation for value creation in other clean energy technologies, particularly in the automotive sector. However, to realise these potential sources of future energy innovation and exports, there is an opportunity for better alignment between Mexico's R&D spending and the technology areas where it already possesses technical capabilities – such as mass-manufactured components and finished products – as well as more researchers in the country's clean energy innovation ecosystem.

Country context

Mexico is the 10th most populous country in the world, with an estimated 130 million habitants. It is the 13th largest in terms of territory and has the 14th

largest GDP, whereas it has the 70th largest in GDP per capita. The country has a large income inequality and had a Gini index of 43.3 in 2022, giving it a rank of 30th most unequal globally. In 2021, labour poverty, the share of the population with insufficient income to access the basic food basket, was 38.5%.

Energy sector context

In 2022, Mexico's installed electricity capacity was almost 100 GW and the electricity generation of nearly 350 TWh. Efforts to improve electricity access in the country have increased it from 98.5% in 2015 to 99.2% in 2021; however, this still leaves around a million people without access, particularly in isolated areas with indigenous population. While this electricity access rate is above the 97.6% rate for Latin America, there are challenges for providing sufficient access, as 36.7% of homes live in energy poverty[1].

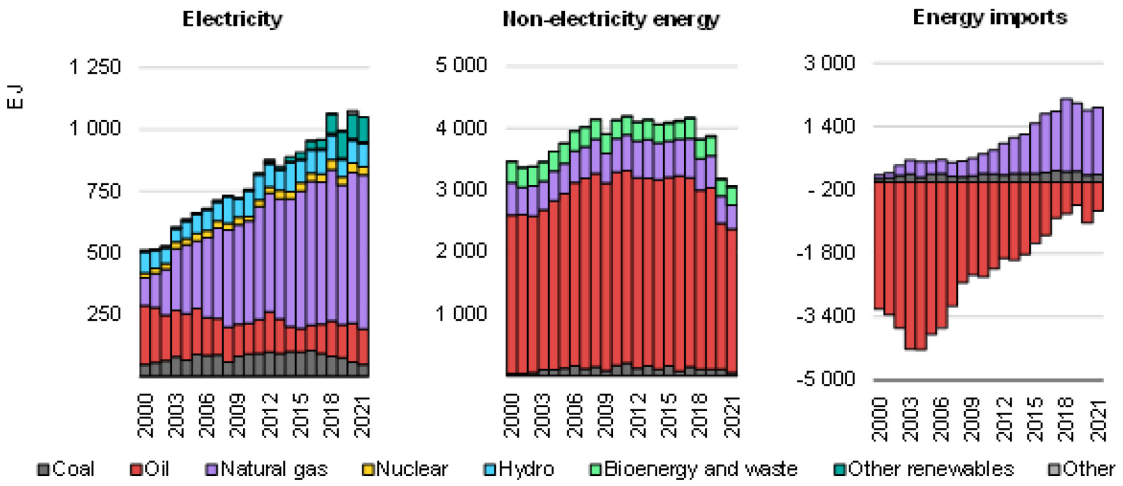
Fossil fuels currently account for 92% of Mexico's total energy supply, a share that has remained virtually unchanged over the past two decades. This is primarily driven by increased natural gas consumption for electricity generation. The country's declining domestic natural gas production, coupled with rising consumption, has resulted in a steady increase in natural gas imports, which now account for 50% of total consumption. Mexico's heavy reliance on fossil fuels and rising electricity demand have driven a significant increase in greenhouse gas (GHG) emissions. In 2022, Mexico ranked ninth globally in terms of absolute GHG emissions, with a total of 820 Mt CO_2-eq. The power sector is responsible for almost a quarter of total emissions, making it the second-largest source after transportation.

Despite Mexico's continued heavy reliance on fossil fuels, the country's electricity generation mix has undergone significant changes over the past decade (Figure 9.1). These changes have been largely driven by the enactment of the Electric Industry Law (LIE) in 2014 and the Energy Transition Law (LTE) in 2015. The LIE and LTE define which technologies can be classified as clean energy sources, establish clean energy deployment targets and a tradeable clean energy certificate system for meeting those targets. Since 2014, there has been a tenfold increase in the installed capacity of solar PV and wind, reaching nearly 20 GW today and accounting for 20% of the total installed capacity. Meanwhile, the installed capacity of natural gas generation grew by less than 15 GW over the same period. However, due to the higher capacity factors of natural gas plants compared to solar PV and wind, they made a more significant contribution to

[1] The energy poverty index used by the authors of this estimation reflects a multidimensional index of energy poverty in the household. This would imply the absence of at least one of the following services or goods that are considered essential to meet basic human needs: i) lighting, ii) entertainment, iii) water heating, iv) food preparation, v) food refrigeration, and vi) thermal comfort.

meeting the increase in electricity demand. This highlights the continued importance of fossil fuels in meeting new power needs despite the growth in renewable capacity.

Figure 9.1 Energy sources for electricity and other uses, and imports, Mexico, 2000-2021



Notes: Electricity and non-electricity energy are shown on a final consumption basis. Imports are shown net of exports. "Other" refers to imports or exports of electricity.

Source: IEA (2024), World Energy Balances.

As a signatory to the Paris Agreement, Mexico presented an updated NDC , in 2022 that included a commitment to achieve an unconditional 35% reduction in GHG emissions by 2030, compared to a baseline scenario. The previous NDC had set a much lower 22% unconditional reduction target. The earlier NDC also outlined specific GHG reduction targets by sector, with the electricity sector expected to play a leading role in the emissions reductions by cutting CO_2 by 31% by 2030 relative to a baseline scenario.

Innovation context

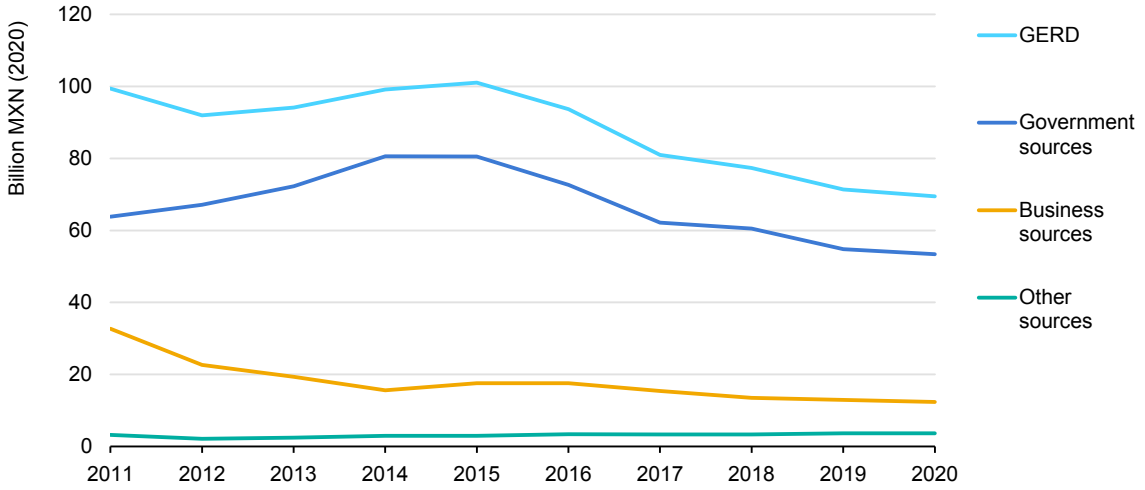
In the 2023 Global Innovation Index, Mexico ranked 58th in the world, a position that the World Intellectual Property Organization (WIPO), the author of the Global Innovation Index, considers to be consistent with its level of development. Among its peers, Mexico ranks 11th in the upper-middle-income category and 3rd in the Latin America and Caribbean region. The Global Innovation Index, recognises Mexico's strengths in areas such as R&D, trade, market scale and diversification, high-tech manufacturing and exports, unicorn valuations, production and export complexity, and creative goods and services. However, it also notes some weaknesses in the institutional environment and operational stability for businesses, a less favourable business environment and policy framework, and

slow labour productivity growth, among others. On science and technology innovation, the Global Innovation Index identifies the top science and technology clusters worldwide, of which Mexico City is in the top 232. In Latin America, Brazil is the only country with clusters in the top 100. Mexico City is in the top 232. In Latin America, Brazil is the only country with clusters in the top 100.

According to UNESCO's database on number of researchers (in full-time equivalent), Mexico had 384 researchers per million inhabitants in 2021, well below the Latin America average of 625 and the world average of 1 283. In terms of scientific publications, as of 2017, Mexico participated in around 0.81% of articles according to information from Scopus.

The General Education Law and the Science and Technology Law both require the government to allocate the equivalent of 1% of GDP to scientific research and technological development. However, in 2020, gross domestic expenditure on R&D (GERD) is estimated at almost Mexican pesos (MXN) 70 billion (Figure 9.2). This equates to just 0.3% of GDP, well below the 1% target (Figure 9.3). The main contributors to GERD are the public and business sectors, with the public sector playing a disproportionately large role. Since 2012, private sector investment in GERD has declined significantly, largely due to the removal of the fiscal stimulus for scientific research and technological development, which was intended to encourage business participation. By 2020, the private sector's contribution to science and technology activities in Mexico had fallen to less than 24% of total spending.

Figure 9.2 Evolution of spending on scientific research and experimental development in Mexico, 2011-2020

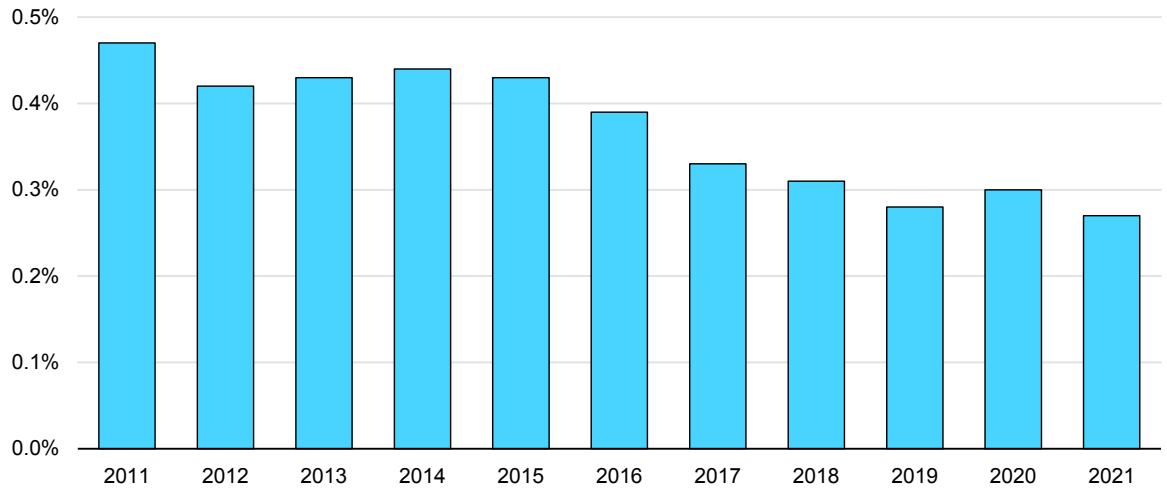


Note: GERD = gross domestic expenditure on R&D.

Source: Conacyt (2021), PROGRAMA Especial de Ciencia, Tecnología e Innovación 2021-2024. - Special Programme on Science, Technology and Innovation, 2021-2024.

There are 13 administrative branches with spending provisions in the federal expenditure budget that have allocations for GIDE. In 2020, the energy sector ranked third in terms of GIDE spending, accounting for 14% of the total, after allocations to the National Science Council and the education sector. Together, these three sectors accounted for over 86% of total government GIDE expenditure. Within the energy sector, the main recipients of public GIDE funds in 2020 were the Mexican Petroleum Institute (IMP), which accounted for 48% of the sector's expenditure; Petróleos Mexicanos (Pemex), with 31%; the National Institute of Nuclear Research (ININ), with 11%; and the National Institute of Electricity and Clean Energy (INEEL), with 10%.

Figure 9.3 Ratio of spending on scientific research and experimental development to gross domestic product in Mexico, 2011-2021



Source: World Bank (2024), Research and development expenditure (% of GDP) - Mexico.

In 2022, the Ministry of Finance and Public Credit (SHCP) proposed that for every MXN 100 of available public spending, MXN 16.8 would be allocated to education. Of this amount, MXN 2.9 would go to higher and postgraduate education, and only MXN 1 to science, technology and innovation. Although only 2% of the federal R&D budget was allocated to clean technologies, investment in science, technology and innovation increases by 4.2% from 2020 to 2021.

The case of solar PV distributed generation in Mexico

There are several policies and initiatives aimed at promoting distributed generation (DG) in Mexico as a means of meeting its clean energy goals and GHG mitigation targets, while improving electricity affordability. The first interconnection request for DG came in 2007, where the development of DG had been driven by

interconnection schemes focused on self-sufficiency, through projects of up to 0.5 MW. The DG systems would exchange power with the grid, effectively storing it for use when demand was higher. Mexican regulations did not allow the sale of energy to the grid, so the scale of projects was limited to meeting their own energy needs. In 2014, the installed capacity of DG in the country was 64 MW.

DG first appears in energy legislation in the Law of the Electric Industry (LIE, by its acronym in Spanish) in 2014. There, it was defined as "the generation of electrical energy carried out by an Exempt Generator in a power plant interconnected to a distribution grid containing a high concentration of load centers". An Exempt Generator (EG) is one whose power plants have a capacity of less than 0.5 MW. They can be connected to the transmission or distribution networks to sell surpluses and purchase power, as long as the EG enters into an interconnection contract. Under the new regulatory regime, small generators can meet their energy needs and also sell energy to the grid. In addition to regulatory changes, response times for grid interconnection requests have been shortened.

As of Q2 2024, more than 450 000 interconnection contracts have been registered, resulting in an installed capacity of almost 4 GW, representing about 4% of the national installed capacity, with an estimated investment of more than USD 5.2 billion. Given Mexico's high levels of solar irradiation, approximately 99.4% of DG capacity is solar PV. While generators are free to choose their tariff regime, almost all opt for net metering, as opposed to other compensation mechanisms such as net billing or buy-all/sell-all models.[2]

Solar PV DG has the potential to significantly support Mexico's clean energy and emission reduction goals by enabling rapid deployment of renewable energy and offering potential savings on electricity bills. However, 99.5% of Mexico's approximately 41 million households currently receive some form of electricity subsidy. The only residential tariff that operates without subsidy is the High Domestic Consumption (DAC) tariff, which applies to users who on average consume above 500 kWh in each two-month period. Other residential tariffs are divided into seven geographical groups based on summer temperatures, with higher subsidies in regions with extreme temperatures to offset cooling costs. To illustrate the impact of these subsidies, the Mexican government estimated that it would spend MXN 575 billion (USD 25 billion) in 2022 on various mechanisms and subsidies to control inflation, of which MXN 73 billion would go to subsidise residential electricity consumption. In 2023, this amount allocated rose to almost MXN 77 billion.

[2] Net metering offsets the flow of electricity fed into and withdrawn from the grid during the billing period. Net billing assigns a value to the flow of electricity received and delivered to and from the grid, which may be different for purchases and sales. The buy-all/sell-all model assigns a sale value to the flow of electricity delivered to the grid.

Solar PV DG generally only provides economic savings compared to traditional grid-connected electricity for consumers under the DAC tariff. However, without the impact of subsidies, solar PV DG would be socio-economically feasible for most consumers. As the introduction of solar PV DG through innovative policy measures could reduce reliance on electricity subsidies and free up public funds for other critical needs in Mexico, several initiatives are exploring how to unlock this potential.

Deployment incentives

Regulatory mechanisms

Mexico has introduced several incentives to encourage the use of renewable energy, including distributed energy resources such as solar PV. One such incentive is the exemption of solar PV modules from import duties. However, in October 2015, the Tax Administration Service (SAT) reclassified solar PV modules into the 'electric generators' tariff category, resulting in a 15% tariff on module imports. In response, the PROSEC programme, introduced in 2018, allowed up to 3 660 solar PV modules per power company to be imported duty-free. In 2019, a court ruling reversed the reclassification, restoring the exemption of solar modules from import tariffs.

Mexico's Income Tax Law (Article 34, Fraction XII), enacted in 2013, further supports renewable energy by allowing a 100% tax deduction for investments in machinery and equipment used to generate renewable energy or efficient cogeneration systems. This benefit includes solar PV DG systems, thereby incentivising investment by allowing it to be deducted.

Another regulatory mechanism supporting the deployment of solar PV DG is that of Clean Energy Certificates (CELs), established under the Energy Transition Law (LTE) and regulated by the Electricity Industry Law (LIE). CELs are issued to Clean Energy Generating Units (CEGUs) that generate electricity from renewable sources. Each CEGU receives one certificate for every megawatt-hour (MWh) of clean energy produced, which can be sold to regulated entities, typically large electricity consumers, required by the LIE to purchase a certain number of CELs each year. By trading CELs, clean energy producers can access additional revenue, making solar PV DG projects more financially viable, particularly those in the medium-scale category.

Financial support programmes

Mexico has implemented several financial support schemes to promote the adoption of clean energy technologies, including solar PV DG systems. These include the Energy Transition and Sustainable Use of Energy Fund (FOTEASE),

a public trust fund, and the Mexican Trust for Electricity Savings (FIDE), a private organisation that manages both public and private resources. Neither scheme is exclusively focused on solar PV DG.

FOTEASE

The Energy Transition and Sustainable Use of Energy Fund (FOTEASE) was created in 2009, based on the previous Law for the Use of Renewable Energy and the Financing of the Energy Transition (LAERFTE), known as the Energy Transition Law since 2015. FOTEASE had an initial budget of MXN 600 million. The objective of FOTEASE is to implement actions in line with the National Strategy for Energy Transition and Sustainable Use of Energy (ENTEASE) and to support the diversification of primary energy sources, promoting and incentivising investment in renewable energy and energy efficiency.

FOTEASE was built as a public trust fund, funded through the Federal Expenditure Budget. It has the purpose of "capturing and channelling public and private, national or international financial resources" to promote priority and strategic areas of national development, energy in this case. The FOTEASE has three main targeted focus areas: technological deployment of renewable energy or equipment to reduce the use of energy; provide a benefit to the society; and the development of human capital, generating knowledge and training for personnel in the installation, operation and maintenance of the equipment.

FOTEASE is designed to use competitive processes where possible to ensure that resources are allocated to projects that offer the greatest benefits for the amount invested. Likewise, it is supposed to ensure that the public contribution is the minimum necessary to make projects viable, considering other income and incentives that may be received. The allocation and distribution of the fund is intended to balance clean energy and energy efficiency project spending. Its financial instruments include grants, loans, loan guarantees and other forms of financial support.

In the latest report published by FOTEASE in 2023, there were 27 projects active at the end of 2022. Five projects were concluded in 2022. Several of the 32 projects were related to distributed energy resources, such as:

- Support for DG: Encourage the use of electricity generated from clean energy sources to meet the ENTEASE targets. Facilitated access to new distributed clean generation technologies by providing incentives for the purchase of PV systems and efficient combined heat and power. Developed a more competitive product market that allowed for lower prices for PV systems and efficient cogeneration. It had a budget of MXN 100 million (about USD 5 million).
- Massive Eco-credit Programme for Businesses: Supported micro, small and medium enterprises in accessing preferential credit to replace inefficient

equipment with new high-efficiency equipment, as well as promoting technologies that help reduce consumption from the grid, including solar PV DG.

- Installation of solar PV cells in primary schools: Installed PV systems in twenty primary schools to reduce their energy bills. Raised awareness of climate change mitigation, ecology and sustainability among students. The panels consisted of 21.5 kWh modules, reducing the schools' average demand on the electricity grid by at least 20%.
- Sustainable improvement of existing housing: Installation of technologies – such as solar PV systems, fast recovery gas heaters, solar water heaters, thermal insulation, efficient air conditioners, insulating windows and thermal films – in homes.

The "Bono Solar" (Solar Bond) programme, conceived and developed by Iniciativa Climática de México (a non-profit think-tank) and funded by FOTEASE, was designed to transform the existing electricity subsidy for low-income, low-electricity consumption households into a subsidy through a leasing mechanism to finance the installation of rooftop solar panels. Under this scheme, homeowners on subsidised electricity tariffs could make their roof available and lease solar panels from CFE, with monthly payments that could be around 15-20% lower than their current electricity bills. The homeowner received a rooftop solar PV installation with generation capacity 10% larger than their historical consumption, leaving CFE with a surplus of electricity. The aim of the programme was to help citizens become clean energy producers, selling surplus electricity to the grid at a lower cost than CFE's unsubsidised tariffs. This approach was intended to reduce household electricity bills and reduce Mexico's spending on electricity subsidies, freeing up public funds for other national priorities such as health and poverty reduction, while helping to reduce GHG emissions.

The programme set an ambitious target of reaching 4% of subsidised residential users, or about 1.4 million households, over a 15-year period. The first phase required an initial investment of MXN 985 million (USD 55 million) to cover the installation of 32 334 solar roofs. However, despite the potential economic and environmental benefits, the programme was ultimately cancelled due to several bureaucratic challenges. The programme has been recently revised and renamed "Hogares Solares" (Solar Homes) for implementation during the next presidential term from 2025.

The CSOLAR Fund, also designed by Iniciativa Climática de México and financed by the CSOLAR Guarantee Fund with MXN 96 million (USD 5 million) from FOTEASE, is designed to facilitate the financing of solar PV systems for small and medium-sized enterprises (SMEs) in Mexico. The programme focuses on the deployment of solar PV DG systems with capacities below 500 kW, targeting unsubsidised commercial and industrial users. Financing of up to MXN 15 million (USD 0.8 million) with a fixed annual interest rate of 13% (lower than typical

market rates), which may be adjusted, is offered and has a maximum repayment term of seven years. Additionally, CSOLAR offers partial loan guarantees via Mexico's development bank, Nacional Financiera (NAFIN), in collaboration with local financial institutions that have solar PV portfolios. The programme uses Mexico's Reliable Supplier Initiative as a means of quality assurance and provides support to financial institutions for the creation of tailor-made solar PV financing solutions. Finance is complemented by educational campaigns to raise end-user awareness of the benefits of solar PV DG.

FIDE

Another notable player in the allocation and distribution of resources for clean energy technologies in Mexico is the Mexican Trust for Electricity Savings (FIDE), a private organisation with public-private participation created in 1990 by initiative of Mexico's state-owned "Comisión Federal de Electricidad" (CFE, Federal Electricity Commission). FIDE's mission is to develop and implement initiatives that promote the efficient use of electricity and the generation of renewable energy, thereby supporting both economic and social development. Through various support programmes, FIDE provides financial assistance for distributed solar PV generation projects, offering interest rates lower than those typically available in the market. For example, the "Eco-crédito Empresarial" programme offers SMEs a financing rate of 14.75% over five years for loans exceeding MXN 250 000. The "Paneles Solares para tu Casa" (Solar Panels for Your Home) programme provides a 25% grant from the Energy Secretariat and 75% financing at a preferential rate for five years, targeting low-income households in regions with extreme temperatures and high electricity bills.

In addition to financing, FIDE also offers the "Sello FIDE" (FIDE Seal), a voluntary certification that guarantees specific energy efficiency and safety standards. The FIDE label assures customers of a product's energy savings, maintenance requirements and expected lifespan. It is awarded to a variety of products, including lighting, appliances and solar PV systems, and has been widely adopted by prominent manufacturers. More than 600 companies have entered the Mexican distributed PV market, with most of their products certified under the FIDE label, whether produced by national or international companies. Solar PV modules bearing the FIDE Seal are also eligible for FIDE financing.

Although Mexico does not have a legal requirement for certification of solar PV DG module installers and maintenance services, several voluntary certifications have been developed. The National Council for Standardisation and Certification of Work Competencies (CONOCER), a sectoral body under the Ministry of Public Education, has issued several certifications aimed at professionalising the sector. These include Competence Standard EC0586.01 for the installation of PV systems in residential, commercial and industrial buildings, and Competence

Standard EC1181 for the supervision of such systems. For example, EC0586.01 outlines the main responsibilities of installers working with low-voltage (up to 2 000 V) non-battery backed PV systems in residential, commercial and industrial environments. Various institutions, including FIDE, offer training to prepare workers to apply for these certificates.

Bridging deployment needs and innovation aspirations

Mexico's solar PV DG sector is facing the challenge of supporting the rapid expansion of renewable energy while simultaneously driving technological innovation. The current policy landscape offers preferential support for market deployment through financial incentives, CELs and a favourable regulatory framework. However, this focus on expansion can overshadow the need for technological advancements that could improve system efficiency, lower costs, and enhance integration with the national grid, while creating jobs and broader economic welfare for society as a whole. Without a stronger focus on innovation, the sector may miss out on the opportunities that innovation could bring to the country. While Mexico has made impressive progress in deploying distributed solar PV systems, its capacity for technological innovation in this field appears to be underdeveloped. Despite various financial and policy support mechanisms to drive market growth, few schemes explicitly support technological innovation, something that could make Mexico more competitive in the global clean energy market.

R&D efforts have been modest, although the Mexican Energy Innovation Centres (CEMIEs) have worked in this area. The CEMIEs, created by the Conacyt-Sener-Energy Sustainability Fund, were designed to create innovation alliances to address scientific and technological challenges related to the sustainable use of energy. Among the various CEMIEs, which cover wind, geothermal, ocean and biomass energy, CEMIE-Sol focuses specifically on solar technologies. Like its counterparts, CEMIE-Sol was created to overcome the scientific and technological barriers within Mexico's energy sector. These centres aim to foster collaboration between academia and industry, promote R&D efforts and build human capital. While these initiatives may contribute to the long-term growth of the sector, their focus on capacity building has not yet led to significant technological advances, largely due to limited public and private funding and weak links between academia and the private sector.

In addition to the CEMIEs, Mexico has launched the "Investigadoras e Investigadores por México" (Researchers for Mexico) programme, led by the country's Science Council. This initiative places PhD scientists in public institutions and promotes collaboration between academia and the public sector. It evolved from the 2014 "Cátedras Conacyt" (Conacyt Chairs) programme that aimed to attract young doctoral graduates to research centres and universities. In 2023, it

was updated with a mandate to place doctoral graduates in federal public administration institutions to improve the dissemination of scientific and technical knowledge, inform policy development, and encourage science-based public policy implementation. Unlike researchers in academic institutions, those placed in public administration are not required to publish scientific papers. Energy is one of the three priority areas of the programme.

Public funding mechanisms such as FOTEASE include goals to support technological innovation, but their main focus remains on broader clean energy deployment and capacity building. While these efforts can indirectly support innovation, they are not specifically designed to drive technological improvement. Instead, the focus is on the efficient deployment of clean energy systems, with less direct support for advancing new technologies. Programmes such as PROSENER have recognised the critical need to promote science, technology and engineering to develop supply chains for the manufacture of clean energy equipment. However, the level of direct added value in Mexico's solar PV supply chain remains relatively low. Although the country has some capacity to manufacture solar PV modules, it imports most of the high-value components, particularly PV cells. There is an opportunity for Mexico to improve its domestic manufacturing capacity and increase value added within the supply chain.

There is great potential for Mexico to improve its solar PV innovation through increased collaboration between the academia, public sector and the industry and the expansion of domestic manufacturing capacity, particularly in higher value-added segments. The growing use of smart grid technologies and energy storage solutions also presents an opportunity for Mexico to improve the efficiency and feasibility of integrating solar PV DG. As the country continues to build its clean energy manufacturing sector, it has the potential to develop its own solutions tailored to the local market. This hands-on approach, combined with more targeted investment in R&D and innovation in DG technologies, could enable Mexico to strengthen its position in the global clean energy supply chain and ultimately become a leader in solar PV technological innovation, particularly given its proximity to some large markets such as the United States.

Findings

Mexico's strong manufacturing sector, currently ranked 7th in the world for manufacturing output, provides a solid foundation for expansion into clean energy technologies. Mexico's expertise, skilled workforce and capabilities in sectors such as automotive manufacturing are highly transferable to clean energy technologies, including solar PV. A manufacturing base in a fast-moving technology area can be a source of learning-by-doing, incremental innovation in components and final products, and spin-off businesses. However, such outcomes are less likely in the absence of functioning innovation ecosystems.

Over the past decade, Mexico's policies and favourable regulation have driven the deployment of DG, particularly solar PV, from 62 MW in 2014 to nearly 4 GW by the first half of 2024. This represents around 4% of the country's total electricity generation capacity today. Mexico is internationally competitive as a major manufacture of mass-produced high-tech products, yet the rapid deployment of solar PV was achieved via imports and was not accompanied in the first decade by investments in domestic manufacturing to meet the rising solar PV demand. However, the consistent year-on-year growth spurred the emergence of numerous small distribution companies specialising in the installation and maintenance of solar PV systems. While policies were effective in incentivising deployment, they were not complemented by policies to enhance Mexico's technical capabilities in the sector, for example through R&D and projects involving academia, public institutions and the private sector, including projects with a social perspective.

As trade tensions between the United States and China have increased and with the passing of the US Inflation Reduction Act in 2022, Mexico investment in solar PV manufacturing capacity has increased. By 2023, domestic solar PV module manufacturing capacity had surged to 2.5 GW per year, driven by Mexico's established manufacturing capabilities and strategic proximity to major markets such as the United States. This growing capacity positions Mexico as a potential key player in the global clean energy supply chain, creating opportunities for innovation through learning-by-doing, as the manufacturing base can support innovation under the right conditions. Near-term opportunities may be more closely related to components, manufacturing and assembly, which can evolve into more sophisticated innovations over time.

By capitalising on its comparative advantages in manufacturing and access to the North American export markets, Mexico has an opportunity to enhance the contribution of clean energy exports to its GDP and make a more substantial contribution to global clean energy technology markets. In 2021, its imports of solar PV cells and modules, at USD 1.3 billion, far exceeded its exports, at USD 140 million. By steadily strengthening its innovation ecosystems for products such as solar PV, electric vehicles and lithium-ion batteries, Mexico could capture a higher share of the value in these supply chains. This would be in line with the government's stated priority of strengthening the country's innovation capacity overall. Among other measures, this could be supported by aligning its R&D spending with international benchmarks and increasing the number of researchers. Currently, Mexico has half the number of researchers per million inhabitants than the Latin American average. By integrating energy technology innovation into its development strategy, Mexico could unite developmental goals, such as reducing energy poverty, with industrial and environmental policy objective. Furthermore, Mexico's renowned capabilities in public policy evaluation, supported by long-standing and experienced institutions in conducting them, would be likely to give it an advantage for learning the lessons of addressing these overlapping objectives and honing its approach.