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CLEAN ENERGY INNOVATION IN LATIN AMERICA

Justin Miller and Lisa Viscidi

Innovation is an important driver for economic competitiveness, job creation and improved trade balances. The global challenges presented by climate change are creating opportunities for countries around the world to boost innovation in the growing clean energy sector. Technological breakthroughs in recent years have helped reduce costs for clean energy solutions, from batteries for electric vehicles to solar power panels, and made possible energy consumption from new sources such as advanced biofuels and waste.

Clean energy research and commercialization have taken off over the last decade. The annual number of clean technology patent documents more than tripled between 2000 and 2014,[1] while venture capital (VC) investment in the clean tech sector overall doubled in 2010-2014 compared to the previous five years, with most clean tech research and investment focused on energy.[2] But more needs to be done. Governments must triple annual spending on energy research and development (R&D) to more than $50 million to meet climate change mitigation goals, according to the International Energy Agency.[3]

The majority of clean energy technologies have been developed in highly industrialized nations, particularly the United States, Japan and European Union countries. In 2014, these countries together held almost two thirds of the world's clean tech patents – the majority of which are in energy-related sectors, such as clean transportation, renewable energy generation, energy efficiency and energy storage (see Figures 2 & 3).[4] However, emerging markets are increasingly leading clean energy innovation. China, for example, has seen the largest growth in clean tech patent filings in recent years. [5]

The global challenges presented by climate change are creating opportunities for countries around the world to boost innovation in the growing clean energy sector.

Foreword

I am pleased to present "Clean Energy Innovation in Latin America," a report by Justin Miller, Clean Energy Consultant – Emerging Markets at Nexant and Lisa Viscidi, Director of the Energy, Climate Change and Extractive Industries Program at the Inter-American Dialogue.

This report examines clean energy technology development in Brazil, Mexico and Chile, which are among the Latin American countries with the greatest potential to expand clean energy research and commercialization. All three countries are part of "Mission Innovation," a global initiative to accelerate public and private clean energy innovation, which was launched during the 2015 United Nations climate talks in Paris. Member countries have committed to double clean energy research and development spending over the five years to 2020.

This report is based largely on interviews with experts from government, academia and the private sector in each country. Although data on clean energy patents, investment and start-ups across the region is scarce, the report reviews a number of trends and statistics that shed light on the status of clean energy innovation in Latin America.

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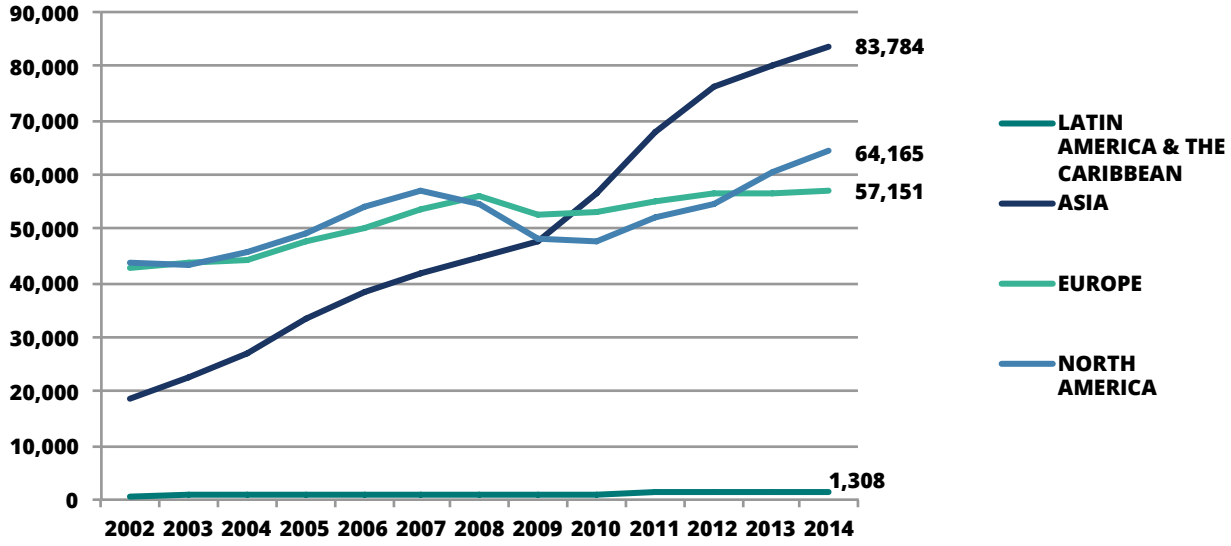
The Dialogue's Energy, Climate Change and Extractive Industries program informs and shapes policies that promote investment while encouraging economically, socially and environmentally responsible development of natural resources. The views expressed in this report are those of the authors and do not necessarily reflect the perspectives of the Inter-American Dialogue, Nexant or our partners or sponsors.

MICHAEL SHIFTER
President

This report examines clean energy technology development in Brazil, Mexico and Chile, which are among the Latin American countries with the greatest potential to expand clean energy research and commercialization.

FIGURE 1: PATENT APPLICATIONS VIA THE PCT (2002-2014)*

Source: World Intellectual Property Organization (WIPO); Analysis: CAF – Development Bank of Latin America



***PCT:** The Patent Cooperation Treaty (PCT) assists applicants in seeking patent protection internationally for their inventions, helps patent Offices with their patent granting decisions, and facilitates public access to technical information relating to those inventions. By filing one international patent application under the PCT, applicants can simultaneously seek protection for an invention in 148 countries throughout the world.

In Latin America, progress has been slower. Latin America trails other regions across many indicators of innovation in energy and other sectors, filing fewer patents, investing less in technology R&D and receiving far lower royalties (See Figure 1).[6]

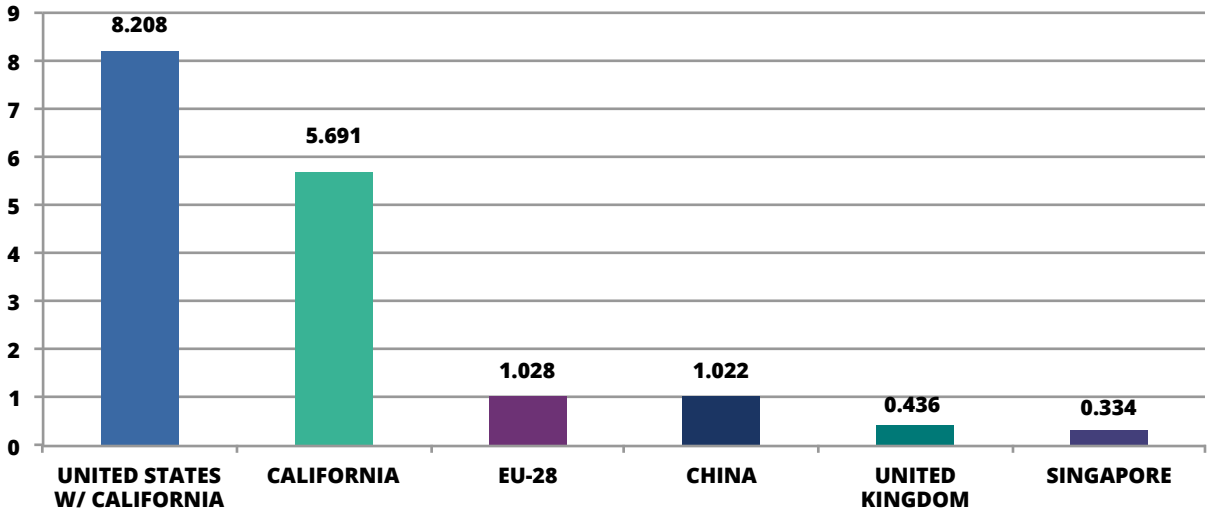
Yet, clean energy innovation in Latin America is critical because even the application of existing technologies developed outside of the region requires researchers to adapt solutions to local conditions. Moreover, clean energy innovation offers an opportunity for Latin American countries to boost economic growth and employment, increase foreign currency inflows through technology exports and licensing royalties and transition their economies toward higher value products and services.

Latin American countries face many barriers in developing clean energy technologies, as our report demonstrates. Among the top barriers to clean energy innovation are access to capital, inadequate government incentives and lack of industry-academia ties.

To bring groundbreaking technologies to market, entrepreneurs need access to capital and an innovation ecosystem that allows them to take risks. VC is particularly important to fund clean energy start-ups because of its focus on early stage, high risk investments. In Latin America, investors tend to be more risk-averse than their counterparts in places like California, and there is very limited VC allocated to technology development. Latin America also has very few clean energy companies listing stock in local capital markets, another potential form of raising funds. Even when capital is available, local regulations penalize risk-taking, for example because of weak bankruptcy legislation in many countries. These conditions pose major barriers to entrepreneurship and innovation in Latin America in general and for clean energy innovation in particular.

Clean energy innovation requires strong government support and incentives to drive both supply of new technologies and demand for clean energy solutions. Government support –through public investment in R&D, clean tech clusters and fiscal incentives – is needed to encourage researchers to create and improve new products and services. Governments can also provide incentives to create domestic markets for clean energy solutions through policies such as public procurement programs requiring minimum levels of domestically developed technology inputs. While Latin American governments do invest in R&D efforts, investment is still too low and is not directed toward the most commercially relevant research.

FIGURE 2: CLEAN TECHNOLOGY VENTURE CAPITAL INVESTMENT IN 2014 (BILLIONS OF USD)
Source: Next 10 California Green Innovation Index



For new technologies to be applied commercially, they need to serve a market need. This requires researchers and government entities supporting R&D efforts to carefully coordinate their work with the private sector to ensure that research in the laboratory will eventually lead to a commercially-viable product or service. However, in Latin America, there is often insufficient communication between academia and national or foreign industry players. Researchers are too focused on academically oriented science rather than technology development with business applications. Moreover, many Latin American researchers file patents only in their own countries, forgoing opportunities to protect and market their inventions in larger, more developed markets in Asia, the United States or Europe (See Figure 7).

Through clean energy innovation, Latin America can boost economic growth and employment, increase technology exports and transition toward higher value products and services.

Despite these challenges, there is great potential for growth in clean energy innovation in the region. Its geography provides abundant natural potential for renewable energy. The region also boasts many highly qualified researchers and top notch research institutions that are developing promising new technologies. Latin American countries have already pioneered technologies in certain niche areas, such as biomass, and are innovating to adapt existing technologies to local conditions. Large economies in the region have a particular incentive to promote innovation locally because clean energy businesses have a large potential market for their goods and services.

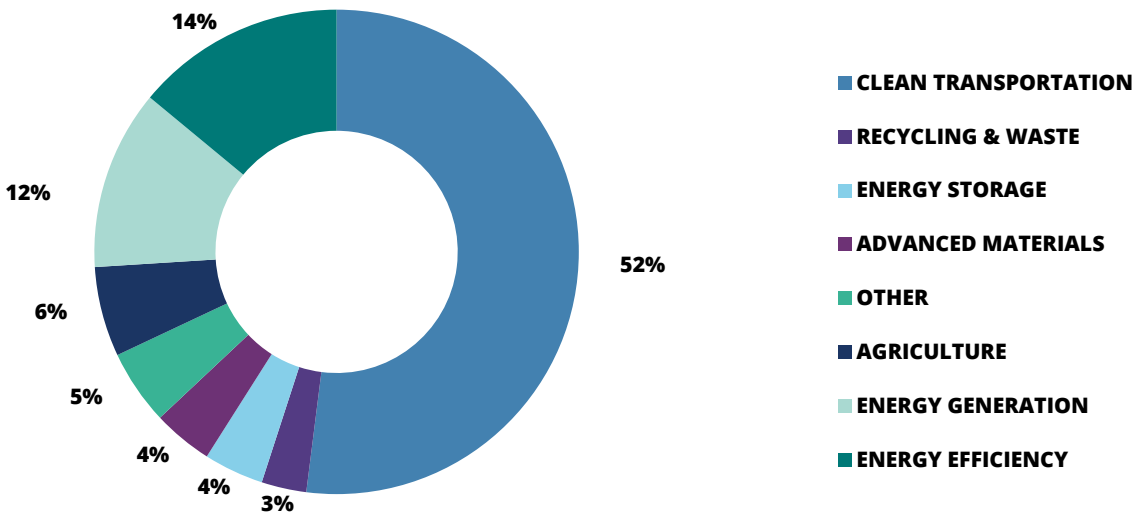
In addition, some researchers from outside of Latin America are patenting their clean energy technologies developed elsewhere in Latin American countries, particularly Brazil. Applicants tend to file patents in markets where they plan to manufacture or sell their products, so this trend suggests that researchers see strong potential to tap the region's market of clean energy consumers.[7]

Brazil

Brazil is the clear leader in clean energy innovation within Latin America. The region's largest economy has been a global leader in biofuels production for decades. The country also boasts a relatively clean electricity matrix,

FIGURE 3: GLOBAL VENTURE CAPITAL INVESTMENT IN CLEAN TECHNOLOGY COMPANIES BY SEGMENT (2014)*

Source: Cleantech Group LLC. Analysis: Collaborative Economics



***Note:** Other includes water & wastewater, smart grid, air & environment and green buildings

with most power generated from hydroelectricity, as well as a growing share of wind and solar – providing a large potential market of clean energy consumers. Its universities and research institutions have produced a sizeable volume of intellectual property, particularly in bioenergy, including biogas and biomass.[8] Strong government support and corporate heavyweights in the energy sector have helped Brazil surpass other Latin American countries in clean energy innovation. Nevertheless, smaller clean energy companies have struggled in Brazil's challenging start-up climate – crowded out by larger players, burdened by cumbersome bureaucracy and high taxes and faced with insufficient public R&D spending and little clean tech-focused VC.[9]

Clean energy technology development

Brazilian researchers have focused on a wide range of clean energy technologies, but bioenergy has received the most attention, thanks to Brazil's natural resource endowments, well-established agro-business companies and long-standing government support. Brazilian universities and associated researchers have focused much of their work on improving the chemical qualities of sugarcane harvests and increasing yields, but technologies have also been developed in areas such as biodigestion for biogas production, waste-to-energy and biomass cogeneration.

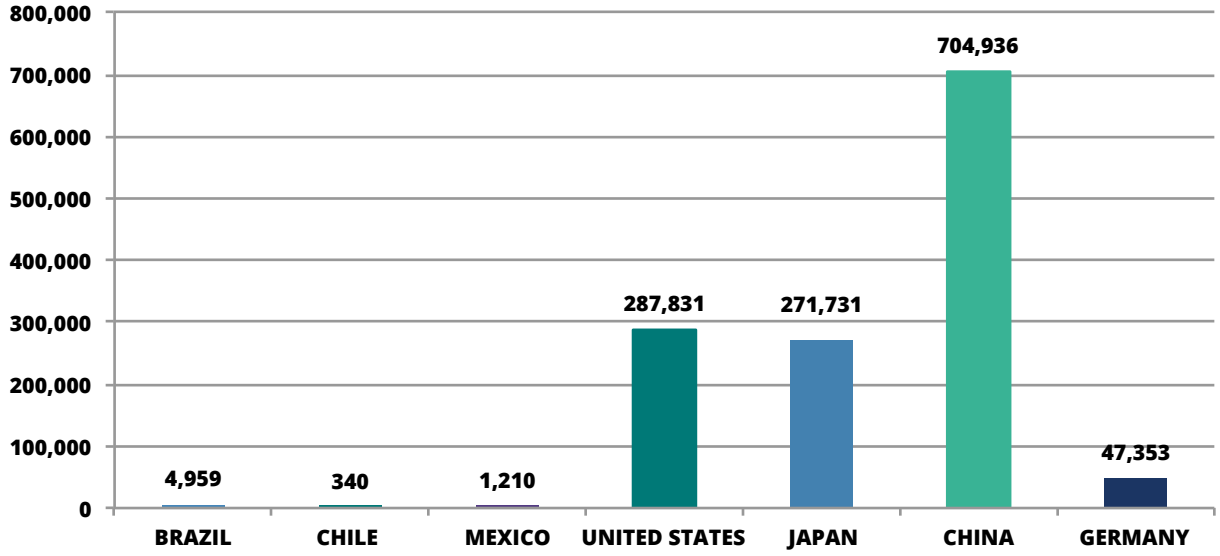
Behind bioenergy, significant resources for research also flow toward wind, photovoltaic (PV) and thermal solar energy and ocean energy. For example, Seahorse Energy, a company born of a business incubator created by Brazil's most prominent energy research center, the Alberto Luiz Coimbra Institute of Post-Graduate Engineering and Research of the Federal University of Rio de Janeiro (UFRJ), has four wave and current energy patents. Researchers have also focused on batteries and fuel cells, power systems, smart grids, carbon capture and sequestration, power transmission optimization and energy efficiency.

Brazil outpaces other Latin American countries both in technology development broadly and in clean energy specifically. Brazilians have filed the largest number of patent applications in the region, including in clean energy (see Figures 6 and 7). The government has accelerated the green technology patenting process through its Green Patent Initiative, under which it has already granted 69 patents.[10]

Unlike in most other Latin American countries, the private sector plays a prominent role in Brazil's clean energy technology sector, dedicating significant financial resources to R&D. This has led to the establishment of private-sector led research centers and meaningful financial and operational linkages between companies, universities and

FIGURE 4: RESIDENT PATENT APPLICATIONS BY FILING OFFICE, 2013 (DIRECT AND PCT NATIONAL PHASE ENTRIES)

Source: World Intellectual Property Organization (WIPO)*



***Resident:** An application filed with an IP office by an applicant residing in the country/region in which that office has jurisdiction. For example, an application filed with the JPO by a resident of Japan is considered a resident application for the JPO. Resident applications are sometimes referred to as domestic applications. A resident grant/registration is an IP right issued on the basis of a resident application.

independent research institutions. Brazil's publicly-listed, state-controlled oil giant, Petrobras, has played a key role in clean energy technology development in Brazil. The company funds biofuels and other clean energy research through its technology and innovation arm, CENPES. Partnerships with large, foreign players, including Shell and Italian company Beta Renewables, have also helped Brazilian biofuel companies to access foreign markets.[11]

Driving technology innovation

Brazil's government has been a major driving force in promoting clean energy technology development. The government provides incentives for clean energy innovation through direct financial resources, low interest loans and regulations requiring electric power industry players to invest in R&D.

Brazil's government directly allocates substantial financial resources to research activities, particularly those of public universities, with bioenergy receiving the largest share of university-based clean energy technology resources. For example, the government provides funding to the National Bioethanol Science and Technology Laboratory, a network of labs that engage in bioproduct-related research activities, such as low-impact automation of sugarcane production, biomass utilization evaluation and sustainability in production processes.

Through the Brazilian development bank, BNDES, the government also lends to the private sector at below-market rates for sustainable infrastructure projects.[12] Although these funds have largely supported clean energy technology developed elsewhere being applied in Brazil, some lending has supported technologies developed in Brazil. BNDES has also provided preferential financing of projects outside of Brazil that employ Brazilian bioenergy technology, such as biorefinery equipment.

The Brazilian government has also put in place regulations to incentivize private sector innovation in the clean electric power industry. Most electric power distribution, transmission and generation companies are required to apply a certain percentage of their net operating revenue to the Brazilian Electric Power Sector Research and Development Program. In contrast to pure academic research, which allows a high degree of freedom and autonomy, the law requires electric power R&D projects to establish well-defined goals and results. Priority areas include alternative electric power generation

sources, energy efficiency, and electric power system planning, operation and control. Projects have included the development of solar PV systems, biogas from liquid waste and domestic wind energy technology.

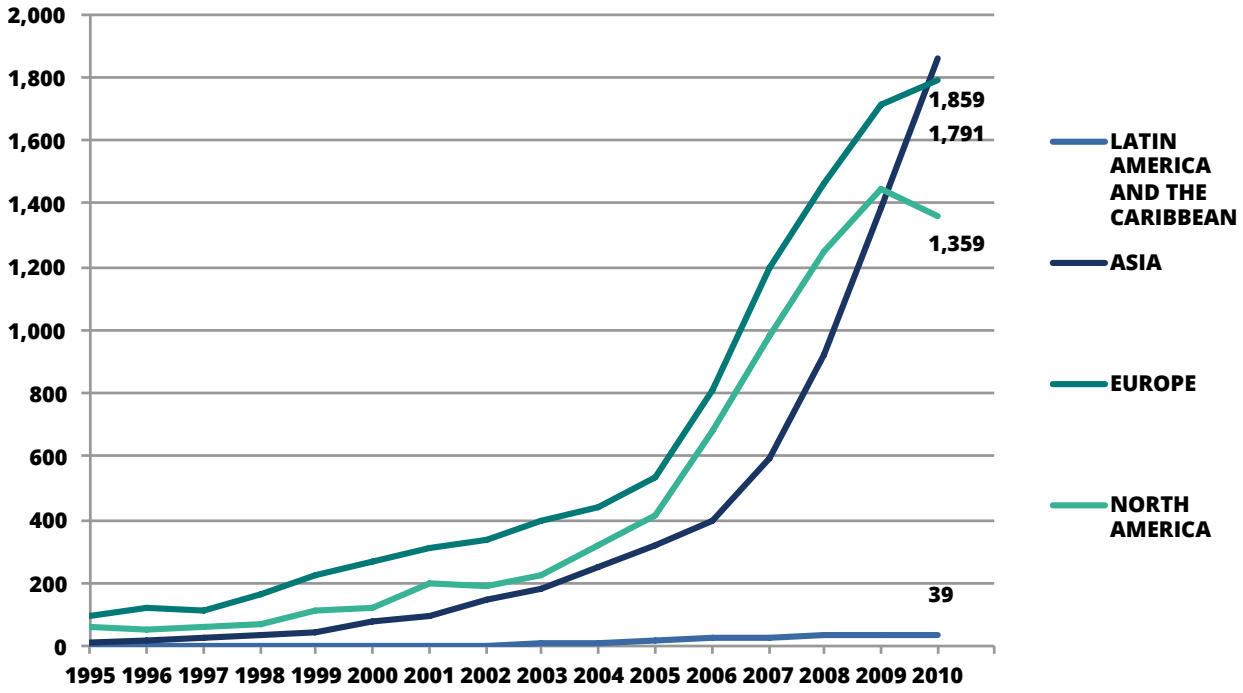
Challenges

While the prominent role of the private sector has been critical in driving innovation, large companies occupy a disproportionate share of the clean energy technology space, crowding out smaller potential private sector actors and discouraging the development of a vibrant clean energy technology start-up culture in Brazil. Furthermore, these large companies focus primarily on their respective core activities. As a result, the clean energy intellectual property (IP) that reaches commercialization is concentrated in a few select areas. Large actors also dominate access to the pool of workforce talent, supplies and technological inputs and scarce private capital for clean energy research and innovation.

Beyond the bioenergy space, Brazil has had limited success in bringing its clean energy IP to market or expanding its clean energy technology manufacturing base. For wind energy, for example, Brazilian firms largely produce only the least valuable components, such as the tower and blades. For solar energy, Brazilian firms are mostly involved in the beginning and early stages, including silicon mining and purification and panel assembly and installation, but are largely absent from the intermediate, technologically-intensive stages where innovation could occur. Even with hydroelectricity – a renewable energy source on which Brazil has long relied – local firms are involved mostly with the construction of the dams and not in the technology-intensive production of the hydroelectric turbines.[13]

Brazil continues to face a wide gap between technology development and commercialization. Clean energy technology players, particularly small- and medium-sized actors not involved in bioenergy, face myriad challenges in bringing their research to market. The excessive time and costs of opening a business and securing IP protection in Brazil weigh on smaller firms' ability to commercialize their research. Securing patent protection from the Brazilian Institute for Industrial Property (INPI) typically takes several years, and although INPI has worked in recent years to reduce this timescale through its Green

FIGURE 5: PCT PATENT APPLICATIONS: ENERGY GENERATION FROM RENEWABLE, NON-FOSSIL FUEL SOURCES
Source: OECD Statistics (2014)*



***Note:** North America does not include Mexico

Patent[14] initiative, Brazil still lags behind markets such as the United States and Europe.[15] Brazilian start-ups also face many barriers to accessing capital and financing their early stage operations. Domestic banks offer high interest rates on their risk-free or low-risk instruments, deterring investment in high-risk clean energy technology. The Brazilian tax code is also unfavorable to small and medium enterprises, while high duties levied on imported scientific equipment further hinder Brazilian researchers.

Conclusion

Brazil's relative success in clean energy technology stems from its early entrance into bioenergy decades ago, which established a long-standing culture of public, academic and private sector support for clean energy R&D that is also helping spur research in other clean energy technology areas such as solar, ocean and small hydro. Nevertheless, bioenergy remains the exception in Brazil -- no other clean energy source boasts such a significant number of researchers dedicated to it or amount of funding behind it. While the involvement of Brazil's major agricultural companies has accelerated bioenergy technology development, it has also crowded the field for small bioenergy start-ups and created barriers for start-ups in other clean tech areas, given limited funds, researchers and related infrastructure.

Brazil's government can take steps to address many of the challenges for clean energy start-ups, for example by lowering taxes and tariffs and streamlining bureaucracy. If Brazil targets small- and medium-sized tech enterprises with these measures, clean energy innovation is more likely to thrive.

Government support and corporate heavyweights in the energy sector helped Brazil surpass its neighbors in clean energy innovation, though smaller companies struggle in Brazil's challenging start-up climate.

Mexico

Mexico has developed many policies to promote clean energy innovation through public and private R&D funding aimed at increasing the supply of clean energy technologies and legislation to encourage market demand for clean energy solutions. Although the volume of Mexico's IP remains low compared to China, India, Brazil and other large emerging markets, the country's universities and research centers have patented a number of innovative clean energy technologies. Despite these efforts, Mexico has very limited evidence of clean energy technology commercialization, due largely to weak links between academia and the private sector, scarce investment and inadequate enforcement of renewable energy and energy efficiency regulations.

Clean energy technology development

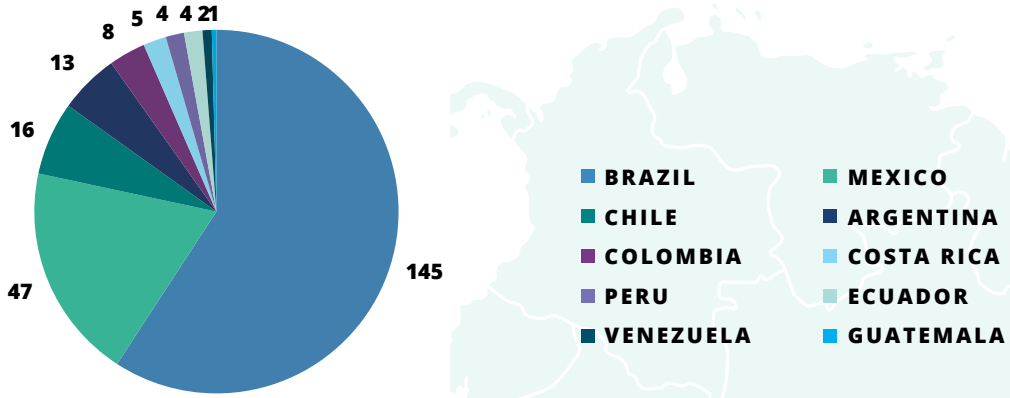
Mexico has a number of clean energy technology patents and patent applications in progress, many of which are focused on renewable energy sources, such as solar and wind, and energy efficiency. Innovative efforts include technology for solar refrigeration, solar cook stoves and solar lighting as well as technology that allows escaping heat from calcination ovens to be captured and reused. However, most of these technologies have not reached the commercial stage. Mexican start-ups have had more success in commercializing biodiesel technologies, though these companies are very small in scale and their impact on the market is limited. One patent by Green Zone, a Mexican energy technology company, covers the use of renewable vegetable oil to reduce the viscosity of heavy hydrocarbons, eliminating the need for the injection of water vapor and petroleum derived chemical compounds while reducing costs. More recently, Mexico has put significant funding into developing geothermal technologies through its Geothermal Innovation Center. As a volcanic region, Mexico has significant potential for geothermal, a firm energy source that can complement intermittent sources such as wind and solar.

Mexico's numerous universities and research centers working in clean energy technology development contribute to IP creation through the training of electromechanical, industrial and chemical engineers, and most of the country's clean energy technology developers who solicit patents hold a university-level degree in these areas. Some of the leading organizations in developing clean energy patents have been public universities, including the Instituto Tecnológico y de Estudios Superiores de

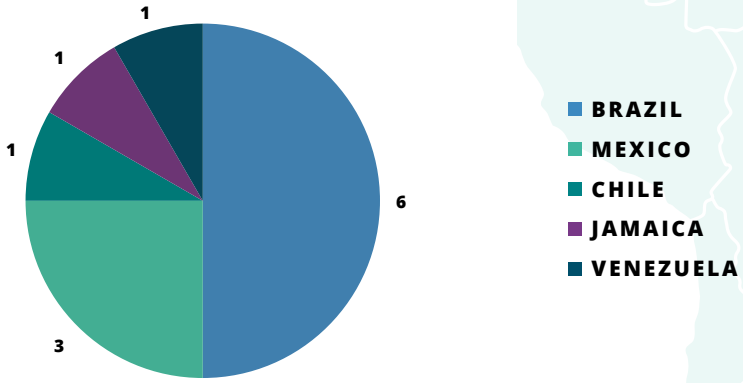
FIGURE 6: PCT PATENT APPLICATIONS BY TYPE

Source: OECD Statistics (2014); Analysis: CAF – Development Bank of Latin America

A: PCT PATENT APPLICATIONS FOR ENERGY GENERATION TECHNOLOGIES USING RENEWABLE NON-FOSSIL FUEL RESOURCES (1995-2011)



B: PCT PATENT APPLICATIONS FOR COMBUSTION TECHNOLOGIES WITH MITIGATION POTENTIAL (1995-2011)



C: PCT PATENT APPLICATIONS FOR BUILDINGS AND LIGHTING ENERGY EFFICIENCY TECHNOLOGIES (1995-2011)

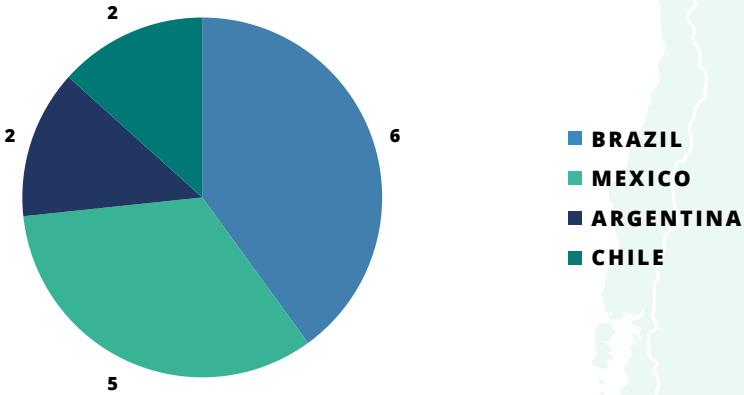
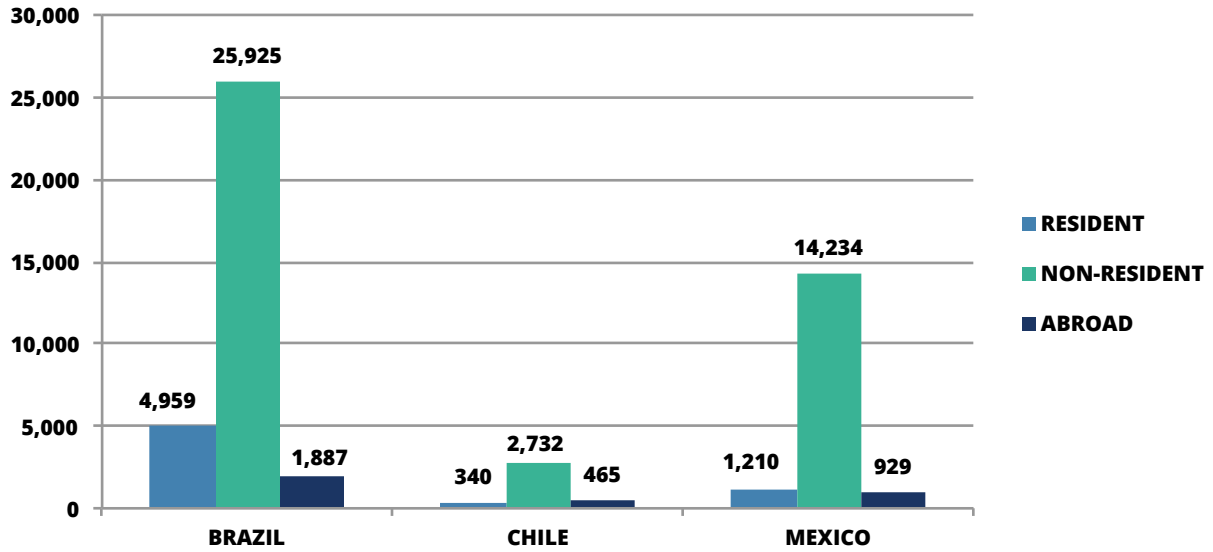


FIGURE 7: TOTAL PATENT APPLICATIONS 2013 (DIRECT AND PCT NATIONAL PHASE ENTRIES)*

Source: World Intellectual Property Organization (WIPO)



***Resident:** An application filed with an IP office by an applicant residing in the country/region in which that office has jurisdiction. **Non-resident application:** An application filed with a patent office of a given country/jurisdiction by an applicant residing in another country/jurisdiction. **Abroad:** An application filed by a resident of a given country/jurisdiction with a patent office of another country/jurisdiction.

Monterrey, the Universidad Nacional Autónoma de México (UNAM), the Universidad Autónoma Metropolitana and the Instituto Politécnico Nacional.

Driving technology innovation

To increase the supply of indigenous clean energy technology on the market, the Mexican state has allocated financial resources through the National Council for Science and Technology (CONACYT) – in collaboration with other public entities, such as the energy ministry and state utility, the Federal Electricity Commission (CFE) – to provide early-stage investment to clean energy technology companies. CONACYT also co-invests with state governments in locally-focused, regionally-appropriate clean energy technology innovation, principally solar and wind energy, organic waste and biomass. Additionally, the government has established tax incentives to nurture scientific and technological R&D and stimulate clean energy technology innovation and entrepreneurship. Multiple private investment funds in Mexico also provide early-stage investment in clean energy technology companies using purely private capital or public and private funding through a co-investment vehicle.

The Mexican legal and regulatory framework has also provided impetus to clean energy technology supply through statutes such as the Science and Technology Law, which aims to create university-based technology hubs and establish scientific and technological information repositories at higher education and research institutions. In 2015, UNAM, in partnership with Mexican firm Green to Energy (G2E) and the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food, launched the Center for Technology Transfer of Biomass Gasification, which researches biomass solutions that are viable for conditions in Mexico. In addition, several programs at both the federal and state levels promote entrepreneurship, including in clean energy technology, providing entrepreneurs with technical assistance, visibility and networking opportunities.

To boost demand for clean energy, the Mexican state has established several mechanisms to incentivize clean energy technology solutions among consumers, businesses and other market segments. These mechanisms include fiscal incentives such as a tax on the sale or importation of certain fossil fuels based on their carbon content and tax rules allowing for accelerated depreciation of renewable energy generation assets.

Mexico's energy reform, approved by congress in December 2013, also provides incentives for renewable energy demand. The reform opens electric power generation, transmission and distribution to private actors that compete with CFE. This is expected to clear a path for greater competition in the electric power market, lowering costs, including for renewable energy generation. A separate law under the reform also requires certain power market participants to purchase clean energy certificates from renewable power generators. The Geothermal Energy Law, another component of the reform, establishes certain operational guidelines for permit holders, promoting innovation in geothermal exploration and production techniques. Other legislation, such as laws establishing energy efficiency standards and requiring public bodies to include criteria on low-emission technology options and energy efficiency in procurement tenders, also promotes clean energy demand.

Mexico has limited evidence of clean energy technology commercialization, due largely to weak academia-private sector links, scarce investment and inadequate enforcement of renewable energy and energy efficiency regulations.

Additionally, federal- and state-level public-private partnership (PPP) laws and regulations have allowed for greater private sector involvement in the construction and management of infrastructure and the provision of public services. PPPs are increasingly common vehicles for private sector actors to provide renewable electric power generation and energy efficient street lighting.

Challenges

Despite these advances, however, Mexico has shown lackluster performance in R&D investment, private sector participation and tech companies' use of IP as a competitive advantage. Mexican research lacks focus on marketable technologies due mainly to weak ties between academia and industry. Moreover, Mexican clean energy start-ups have struggled to raise capital, export technologies or invest in scaling, and weak government regulations promoting renewable energy and energy efficiency mean the market for clean energy technology in Mexico is small.

Mexico's greatest challenge is that the clean energy technology innovation occurring in the country rarely addresses specific needs in the market; in other words, clean energy technology supply rarely meets clean energy technology demand. One reason is that a significant amount of public funding for clean energy technology innovation is distributed through CONACYT, an institution with strong financial and institutional ties to academia. Researchers and supervising faculty, while highly capable in their respective fields, often lack market ties to understand how research in the laboratory will eventually lead to a commercially-viable product or service. The CONACYT-style academic scholarship model provides little incentive for clean energy technology engineers and scientists to gear R&D toward addressing concrete market needs. Moreover, few academic and research institutions require clean energy technology engineers and scientists to engage industry through internships, limiting their exposure to industry needs and practical commercial opportunities.

In addition, in contrast to the model of most US academic and research institutions, Mexican institutions often wholly retain IP for technology developed at their institution, and either largely or wholly retain related royalties. This model undermines the incentive for clean energy technology engineers and scientists to develop clean energy technology IP with meaningful commercial value.

The concept of innovation clusters in Mexico – whereby researchers, universities, entrepreneurs and investors, along with local and federal government policies, support regionally-focused technological innovation with a view to bringing a commercially-viable product to market – remains nascent.[16]

There is also very limited VC allocated to technology development in Mexico, especially when compared to VC tech incubation in places such as Silicon Valley, California, and only a small percentage of the VC allocated to technology development in Mexico is specifically for clean energy. Rather, Mexican VC largely goes toward projects to implement existing clean energy technologies developed

outside of Mexico, such as installation of wind and solar PV parks. Without access to VC, clean energy technology start-ups face liquidity constraints over the long period of time it can take to develop an innovation into a bankable product. Clean energy technology start-ups also face a classic VC "middle-market" conundrum, whereby they need seed investment too large for the capital pool to which small Mexican VC firms typically have access, but the investments are also too small for large VC firms in Mexico given the relatively high agency costs associated with such investments.

Furthermore, weak enforcement of environmental and renewable energy integration and energy efficiency regulations limit the incentive to develop clean energy technology tailored for the Mexican context.

Conclusion

While Mexican researchers and entrepreneurs have struggled to create successful clean energy start-ups, the country has great potential to boost clean energy innovation. Mexico's recent pledge to double clean energy R&D spending over the next five years is an important step, but this funding must be aimed at developing commercially viable products and services that meet market needs.

Chile

Facing a steep bill for liquefied natural gas imports and rising public opposition to new hydroelectric dams, Chile has strong incentives to increase power generation from non-conventional renewable energy sources and improve energy efficiency. However, although Chilean researchers have patented and commercialized a number of clean energy technologies that use renewable sources such as biomass, ocean energy and solar, as well as energy efficiency solutions, Chile remains far behind its larger neighbors Brazil and Mexico. The ease of importing technologies developed abroad, due to the small size of the Chilean market and its openness to international trade, appears to have reduced the impetus for local innovation. The dominant role of public funding and public universities has also restricted private investment in the clean energy sector.

Clean energy technology development

Drawing on its natural advantages, from almost 4,000 miles of coastline to extensive stretches of sunny desert in central and northern Chile, the country has established a number of top notch research centers working to develop renewable energy technologies. The Chilean university system plays a leading role in clean energy R&D and innovation, hosting research centers and contributing researchers and funds to third party centers. In addition, universities often partner with private companies in R&D efforts tied to the company's core competencies. For example, Chile's large mining industry partners with universities to develop renewable energy projects for mining operations.

Chile has long been home to many biomass-focused research centers, but in recent years, wind, solar, ocean and geothermal energies have also gained ground. Chile's Andean Geothermal Center for Excellence models geothermal systems along the Andean mountain range,

The ease of importing technologies developed abroad, due to the small size of the Chilean market and its openness to international trade, appears to have reduced the impetus for local innovation. The dominant role of public funding and public universities has also restricted private investment in the clean energy sector.

including heat-water-rock interaction, structural and tectonic geology, magmatic systems and geophysics. In ocean energy, Chile's Marine Energy Research and Innovation Center focuses on tidal and wave energy with a focus on local coastal conditions. Successful clean tech start-ups include Wilefko, a Chilean company that developed and patented[17] a motor powered by wave energy that has advanced to the commercial stage. Research at the Chilean Solar Energy Research Center includes solar energy for industry and mining, solar energy coordination systems for rural and urban communities and solar energy storage and water treatment. Chilean company Calder acquired a patent for ECOPANEL, a thermal solar panel that is currently sold and installed in Chile. Nonetheless, these success stories are among the few examples of Chilean clean energy technology that has reached the commercial stage.

Driving technology innovation

The Chilean government encourages innovation through policies aimed at building human capital, promoting scientific research and incentivizing corporate innovation. Drawing on input from the public sector, scientific researchers, academia and the business community, government bodies like the National Council on Innovation for Competitiveness and the Government Innovation Committee for Competitiveness formulate policies that benefit universities, research institutes and companies in the clean energy space.

The public sector is the main provider of R&D spending, while private resources also flow to clean energy technology. Chile has several state-backed funds to support R&D, which are largely available through competitive processes based on demand for the research, the strength of the proposal and the prospect of mobilizing private sector co-investment or co-financing. For example, the Chilean Economic Development Agency (CORFO) Technological Transfer Hub Program provides subsidies for R&D in priority sectors, including energy. Likewise, the National Commission for Scientific and Technological Research (CONICYT) has provided resources for R&D in bioenergy and solar energy technology. Nonetheless, Chile lags behind most other OECD countries in total R&D spending as a percentage of GDP.[18]

Challenges

Despite ample government funding and incentives, the country has very low levels of investment in electric power innovation and entrepreneurship, according to a Ministry of Energy-led assessment of prospects for a sustainable energy future in Chile.[19] The dominant role of public sector investment in energy-related research poses several challenges to Chilean clean energy technology development, the study notes. Public investment is rarely targeted toward research that has a clear path to commercialization and often crowds out private sector investment, leading to inflated prices. On the private sector side, Chilean investors and financiers are generally risk-averse, meaning private capital is scarce at the early stages of clean energy technology development.

Insufficient physical and intangible infrastructure to support clean energy technology research and innovation, such as research equipment and installations to house R&D activities, inhibits clean tech development. Chile also lacks technological hubs with institutional arrangements to facilitate public and private sector communication and a seamless pathway between academic research and industry application. Such hubs would also promote innovation in processes, business models, new product and services markets, and technology transfer between domestic and foreign firms. The country also needs more highly trained professionals and technicians in clean energy fields, according to the ministry assessment.

Conclusion

Chile has made laudable efforts in recent years toward "greening" its energy consumption, particularly in electric power through the deployment of proven renewable energy generation technologies. In addition, the country is increasingly improving energy efficiency in the residential, industrial and commercial sectors. However, its progress in locally producing commercially viable clean energy technology has been limited.

To address this lag, the Chilean state should pursue policies to increase overall investment, while ensuring that the private sector takes the lead, perhaps through greater public-private partnership opportunities, co-investment, fiscal incentives and technology hubs with the public, industrial, commercial and academic sectors. There are economic advantages for a small market such as Chile to import foreign-designed technologies rather than develop indigenous technologies for the same applications. However, Chile has abundant opportunities to develop unique clean energy technologies that better fit the local context or draw upon the country's comparative advantages such as ocean and solar resources.

RECOMMENDATIONS

As the three case studies demonstrate, even the leading countries in clean energy innovation within Latin America are far behind many other regions of the world. Yet, Latin American countries have a great opportunity to expand clean energy innovation through various policy measures, including:

- **Improve links with international industry players:** Latin American countries need to expand industry-academia ties, but it may be more effective to connect researchers with foreign private sector players that have more experience in marketing and exporting technologies than domestic firms. Latin American researchers also need to patent more of their technologies in larger foreign markets to increase their exposure to foreign companies and increase royalties. Links with international industry and markets will also help Latin American start-ups to gain access to international capital.

- **Strengthen policies to boost domestic demand:** To boost demand for indigenous clean energy technologies, Latin American countries could establish public procurement programs that require government entities to buy a certain percentage of innovative technologies derived from R&D efforts within the country. Such policies may be the most efficient way to create a domestic market and allow companies, particularly small enterprises, to sell their patented technologies and test their prototypes.

- **Redirect research and development efforts:** Most governments in the region need to increase R&D spending as a percentage of GDP to boost overall innovation (Latin America spends only 0.82% of GDP on R&D compared to 1.84% in Asia and 2.81% in the United States). In the clean energy space, countries would benefit from redirecting even a small percentage of R&D spending toward innovation that is more engineering-based, which would boost research capabilities in energy-related fields.

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