Prologue

By Jeremy M. Martin & Duncan Wood

Mexico has seen a radical change of direction regarding renewable energy since Andrés Manuel López Obrador (AMLO) took office in December 2018.

By 2018, Mexico had held three clean energy auctions for the sale of clean energy and related clean energy certificates to CFE, the state-owned power company. An October 2018 press release from the Ministry of Energy noted that as a result of these auctions, Mexico would receive US$8.6 billion in investment, which would be used to develop 65 solar and wind energy projects.

Under AMLO, Mexico has pursued a very different path. In January 2019, a planned fourth clean energy auction was suspended. The Ministry of Energy then gave notice in December 2019 that it would convene no further clean energy auctions. AMLO himself has publicly denigrated wind power and has shown an obsessive interest in hydrocarbons. Most recently, on April 29, 2020, the independent system operator for Mexico, CENACE, issued an "*Acuerdo*" that indefinitely suspended critical pre-operative tests for new renewable energy projects and gave CENACE broad discretion to disfavor renewables, purportedly to protect the reliability of Mexico's national electric system in the face of COVID-19.

The *Acuerdo* declared that renewable energy undermines the reliability of the national electric system because of its intermittency and other grid integration issues. However, President López Obrador at a news conference on May 6, 2020 explained that the actual objective of the measure was for CFE to have priority in providing electricity to the grid and not private companies.

By most estimations, the *Acuerdo* is legally questionable. Mexico's National Commission for Economic Competition (COFECE) has now issued an opinion holding that, in its present form, the *Acuerdo* may have anti-competitive effects in the electricity generation market. Nevertheless, this measure makes clear AMLO's hostility to renewable energy.

Notwithstanding AMLO's position, renewable energy continues to play an important role and has enormous potential for the future in Mexico. The following paper, by John McNeece, presents the "Economic and Strategic Arguments for Renewable Energy in Mexico." Among other things, the paper shows that solar and wind projects can supply electricity at a cost below that from conventional gas-fired generation and provide economic development benefits. Further, with battery energy storage and available grid management tools, it is possible to manage the intermittency of renewable energy and integrate it effectively into the transmission grid and distribution networks. We are pleased to be able to jointly publish the report and thank John for preparing this rigorous analysis and important contribution to the public policy debate underway in Mexico today with regards to renewable energy, institutions, and the role of the state.

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The Economic and Strategic Arguments for Renewable Energy in Mexico

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There are strong economic and strategic arguments for increased development of renewable energy in Mexico, as follows:

- Renewable energy from solar and wind projects, supplemented by energy storage, is low-cost and reliable. With Mexico's high intensity sun and wind, electricity from these sources can be less costly than electricity from conventional gas-fired generation. Energy storage, together with other grid management tools, converts solar and wind energy into a steady and dependable source of electricity that can be integrated effectively into the transmission grid and distribution networks.

- Low-cost renewable energy plus storage can be a foundation for economic development, including job creation. An adequate supply of cheap, reliable electricity is a necessity for economic growth across the entire economy. There are also direct economic benefits from the development of renewable energy projects and related infrastructure, including construction jobs. Mexico could also seek to foster increased manufacturing and assembly in this sector.

- Renewable energy plus storage can partially replace natural gas for generation of electricity, reducing Mexico's dependence on imported natural gas. Mexico now imports 90 percent of the natural gas consumed in Mexico (other than PEMEX self-consumption), much of which is used for generation of electricity. Less need for natural gas as a fuel for electricity generation means less imports of natural gas.

- Reduced imports of natural gas will help reduce Mexico's hydrocarbon balance of trade, which is presently negative, i.e. Mexico's revenues from hydrocarbon exports, i.e. exports of crude oil, are less than its expenditures for hydrocarbon imports, primarily imports of gasoline and natural gas.

Renewable Energy: Costs, Reliability, and Grid Integration

The winning bids in the final clean energy auction before Andrés Manuel López Obrador was elected President averaged US$20.57 per Megawatt hour (MWh) for electricity (including clean energy certificates) from solar and wind – among the lowest prices ever bid internationally. These

low bids were founded on the long-term decline in the costs of renewable energy technologies as well as Mexico's extraordinary solar and wind resources. However, the Comisión Federal de Electricidad (CFE) has now declined to continue the clean energy auctions, with CFE General Director Manuel Bartlett General arguing that the auction prices for solar and wind energy are a "lie" and will result in higher electricity prices for the Mexican people.

The CFE's position is that the bid results do not take account of the full cost of solar and wind. According to the CFE Director of Finances, a proper cost accounting must include the cost of backup power for when the sun does not shine and the wind does not blow (intermittency); the cost of integrating clean energy onto the grid; and the cost of new transmission capacity to support clean energy. However, even taking account of CFE's concerns, electricity from renewable energy sources can be cheaper than electricity from conventional power plants.

The issues of intermittency and grid integration can be managed effectively through use of battery energy storage. Batteries can "smooth out" intermittency in the course of a day, and extend the supply period, e.g. for solar projects after the sun goes down. Further, batteries can assist with grid integration by absorbing excess power at times when power generation exceeds demand and through frequency regulation (to correct short-term imbalances in supply and demand) and voltage regulation. All of this can be done at a very low price. Mexico does not yet have much experience with energy storage projects, but Mexican energy planners should consider energy storage as an effective mechanism to offset the limitations of renewable energy.

Within the United States, there are numerous hybrid projects, consisting of generation and storage together, and the pricing has been very attractive. A 2017 All Source Solicitation carried out by Xcel Energy in Colorado resulted in 11 bids for wind plus storage with a median price of $21.00 per MWh, 87 bids for solar plus storage with a median price of $36.00 per MWh, and 7 bids for wind plus energy plus storage with a median price of $30.60 per MWh. "Median price" in this case means the "mid-point of the pricing such that 50% of the bids are lower priced and 50% are higher priced," which means that 50 percent of the bids presented were less than the figures shown.

All of the Xcel 2017 bid median prices for generation plus storage were lower than the cost of conventional gas-fired generation. According to Lazard, a prominent investment bank, the levelized cost of electricity in the United States from a gas combined cycle power plant, without tax subsidies, would cost in the range of $44 to $68 per MWh over the life of the plant, assuming a natural gas cost of US$3.45 per million BTUs.

More recently, 8minute Solar Energy agreed to provide the Los Angeles Department of Water & Power, for 25 years, with 200 Megawatts (MW) of solar photovoltaic (PV) generation, plus batteries supplying 100 MW of power over a 4-hour period (i.e. total energy of 400 MWh), at a price of US$19.97 per MWh for electricity plus US$13.00 per MWh for battery support. According to press reports, the total price of US$32.97 per MWh sets a record low for the cost of solar plus storage, with prices cheaper than for electricity from natural gas.

These U.S. prices for electricity do not automatically transfer over to Mexico. Among other things, there are tax benefits in the United States (investment tax credits and production tax credits) that are not available in Mexico. Mr. Tom Buttgenbach, the President of 8minute Solar Energy, estimates that the 8minute-LADWP deal described above, if located in Mexico with a creditworthy buyer, would cost 10 percent more for the cost of the PV generation, and up to 40 percent more for the cost of the batteries. With these additions, the cost of solar plus storage in Mexico would be US$40.17 /MWh, still cheaper than the cost of electricity from natural gas.

Batteries cannot fully resolve all issues of intermittency, i.e. if the sun does not shine or the wind does not blow for several days, nor can batteries resolve all issues of grid integration. However, a 2017 International Energy Agency country survey and analysis shows that utilities in many countries are already managing effectively the intermittency of renewable resources and otherwise integrating those resources into their power systems, at increasingly high percentages of total generation. There are a number of grid integration tools for these purposes, at varying levels of cost. In addition to batteries, the available tools include:

- Increasing the size of the area from which generation can be drawn, even up to large regions, e.g. under the Western Energy Imbalance Market in the western United States, in order to take advantage of production resources across the entire area.
- Integrating solar resources and wind resources in different locations in order to obtain complementary peaks in production on an annual and daily level.
- Improved wind and solar forecasting, often tied to 5-minute dispatch resolution.
- Demand response programs.
- Increased flexibility of conventional power plants on the system to serve as backup.
- Evolving capabilities of renewable generation itself to contribute to reliability, both with respect to solar and wind.
- Ancillary services, some of which can be provided by energy storage, for frequency support, voltage support, and backup when load begins to exceed generation.

The issue then becomes what is the most effective strategy for ensuring grid reliability at the lowest cost. A 2015 study on Integrating Renewable Energy into the Electricity Grid reviewed prior analyses and noted "evidence that integration of large amounts of wind energy, up to 30 percent of total generation, is technically and economically feasible, with integration costs generally less than 10 percent of the cost per MWh of wind and often significantly less."

A more recent Massachusetts Institute of Technology study show that with wide dispersion of wind and solar projects, together with suitable battery energy storage, renewable energy can be reliable and cost competitive for a high percentage of all electricity needs under a deep decarbonization strategy, including even baseload generation, with only a modest amount of conventional generation as backup. This suggests that the integration costs for less aggressive use of renewable energy plus storage would be quite low.

On the issue of transmission, Mexico currently needs new transmission capacity for all forms of generation. Mexico's electricity consumption was 2.4 MWh per capita in 2018, far below other developed countries. Spain, for example, had electricity consumption of 5.5 MWh per capital in 2018. Mexico needs to strengthen its entire national electrical system, including the transmission grid.

An expansion of the grid could bring important benefits for all of Mexico. Analyses of specific transmission projects managed by the Electric Reliability Council of Texas (ERCOT), the Southwest Power Pool (SPP), and the Midcontinent Independent System Operator (MISO) in the United States showed that these projects would reduce electricity prices and more than pay for themselves, with benefits of 2.6 to 3.9 times their costs. Mexico would need to do its own studies, but these results suggest that Mexico's investment in an expanded transmission grid would provide substantial national benefits and would also pay for itself.

Accordingly, the cost of the necessary transmission enhancements should be passed on to all ratepayers and not charged only to renewable energy developers.

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These comments on the cost and reliability of renewable energy plus energy storage rely heavily on U.S. and international examples. Mexico would need to carry out its own grid integration studies and transmission planning studies in order to determine the system support needed, and the related costs, for increased development of clean energy plus storage in Mexico, as well as the corresponding benefits in reducing the price of electricity. Mexico has substantial expertise in planning for the national electric system, as reflected in the annual Programs for Development of the National Electrical System (PRODESENs); it is well equipped to carry out the studies and analysis suggested here.

With the results of its analysis, Mexico could then take promising scenarios for use of renewable energy plus storage and test those scenarios in the marketplace, using a bid process that identifies goals and leaves the approach for reaching these goals to the bidders. Once bids come in, Mexico can then evaluate the bids not only on the specific financial terms offered, but also in terms of the all-in costs, including integration costs and additional transmission network upgrade costs, if any, for interconnection or deliverability. This is the way that Xcel managed its 2017 All Source Solicitation as referenced above. This approach would give Mexico a broader view of total costs for developing renewable energy plus storage projects.

Renewable Energy as a Foundation for Economic Development and Job Creation

Low-cost renewable energy can be a foundation for economic development, including job creation. An adequate supply of cheap, reliable electricity is a necessity for economic growth across the entire economy. This should be a key objective of government energy planners, and it

is now lacking, as shown by the per capita electricity consumption figures presented above. There would also be direct economic benefits from the development of renewable energy plus storage projects.

With respect to direct economic benefits, once Mexico has developed promising scenarios on potential new projects, i.e. wind and solar projects, battery installations, and transmission, it can then generate figures for the necessary investment amounts and the timetable for construction and investment. With that information, it will be possible, using input-output models, such as that provided commercially by IMPLAN, to generate projected figures, for each year of the construction program, on total industrial output, national value added, total labor income, and jobs created. There are readily available examples of this type of economic impact and job creation analysis. The results of the analysis should then be incorporated in the overall cost-benefit analysis for the identified scenarios for development of renewable energy plus storage.

Without that detailed analysis, it is still possible to identify potential economic development and job creation opportunities. The International Renewable Energy Agency (IRENA), in its Renewable Energy and Jobs Annual Review 2019, highlights the socio-economic benefits and job creation that clean and renewable energy can provide, and the challenges presented. Some of the key points are as follows:

- The renewable energy sector now employs at least 11 million people worldwide, with more countries manufacturing, trading, and installing renewable energy technologies every year.
- There are employment opportunities in installation and servicing of renewable energy facilities and, to a lesser degree, in assembly and manufacturing.
- Several factors — including national deployment and industrial policies, changes in the geographic footprint of supply chains and in trade patterns, and industry consolidation trends — shape how and where jobs are created.

Mexico already has robust industries in solar and wind energy. According to the Mexican Solar Industry Association (ASOLMEX), reporting on developments in 2019, Mexico currently has approximately 5,000 Megawatts of installed solar capacity, with 62 solar projects operating in 16 states of the Mexican republic and 64,000 employees at work throughout the solar energy value chain. The Mexican Wind Energy Association (AMDEE) reports that there were 4,935 Megawatts of installed wind energy capacity at the end of 2018 in 54 wind energy parks. At the Mexico Windpower 2020 conference, the President of AMDEE stated that Mexico now has more than 11,000 permanent jobs in the wind energy sector, 7,000 of which are in manufacturing, with the prospect of creating 35,000 more jobs in the next five years.

With the solar and wind industries already in place, there is a strong foundation for further growth in Mexican renewable energy. However, this will require more certainty in the investment environment for construction of long-term projects. In comments that could apply to both wind

and solar, the President of AMDEE called for "certainty for long-term investments, with clear rules for the future of the industry and certainty for projects that already exist."

A 2019 analysis of clean energy jobs in the United States found that nearly 335,000 people work in the solar industry and more than 111,000 work in the wind industry. In addition, approximately 139,000 people work on grid modernization and energy storage. The U.S. Bureau of Labor Statistics forecasts that America's two fastest-growing jobs through 2026 will be solar installer (105% growth) and wind technician (96% growth). This suggests that in the United States, many renewable energy jobs are related to installation and service. Mexico should be able to see substantial growth in these areas as well. However, Mexico should also be able to increase employment in assembly and manufacturing, and in the buildout of Mexico's transmission grid.

Mexico is one of the leading manufacturing centers in the world, with a highly capable workforce. It should be able to leverage this experience to build capability in the manufacturing of renewable energy equipment. Mexico has a large market itself, with a current population of roughly 129 million; however, with NAFTA and its planned replacement, the USMCA, Mexico also has access to the U.S. and Canadian markets with zero or low tariffs, assuming that the assembly or manufacturing processes carried out in Mexico are sufficient to establish that the produced goods meet the applicable rules of origin.

Nevertheless, creating a manufacturing base, in this case for renewable energy equipment, is not a simple matter. As the 2019 IRENA report indicates, national deployment and industrial policies, changes in the geographic footprint of supply chains and in trade patterns, and industry consolidation trends all shape how and where jobs are created. Mexico would need to analyze in depth all of these factors and establish a robust strategy to attract renewable energy manufacturing. The most direct path would be to work with existing low-cost manufacturers to convince them to build manufacturing facilities in Mexico, with the understanding that they would use Mexican materials and personnel to the greatest extent possible.

Renewable Energy Could Partially Replace Natural Gas in Future Years to Generate Electricity

Mexico is highly dependent on natural gas imported from the United States. A high percentage of that imported natural gas is used to generate electricity. Renewable energy could partially replace natural gas in the future as a source for the generation of electricity, thereby reducing Mexico's dependency on imported natural gas. This in turn carries out the principle of energy sovereignty for Mexico, a core objective of President López Obrador.

According to a 2019 Report from Mexico's National Hydrocarbons Commission (CNH), Mexico at mid-year 2019 consumed 8.042 billion cubic feet per day (bcfd) of natural gas, while producing only 2.587 bcfd. Imports of 5.455 bcfd made up the difference. According to the report, these imports constitute 90 percent of the natural gas consumed in Mexico other than PEMEX self-

consumption and 67percent if PEMEX self-consumption is included in the calculation. Substantially all the imported gas comes from the United States. Commenting on the dependency this entails, the CNH report indicates that of all the countries in the world that are highly dependent on imported natural gas, only Mexico relies on a single country for substantially all of its imports. Mexico's dependency on the United States for its natural gas needs is unique in the world.

A 2018 Report by Mexico's Ministry of Energy provides some data on how much of the imported natural gas is used for electricity generation. According to that report, the percentage consumption of natural gas for 2017 by usage was as follows: 50.8 percent for electricity generation; 26.4 percent for the petroleum sector; 21.1percent for the industrial sector; and the balance for residential use, services, and autotransport. If we measure imports as a percentage of consumption excluding the petroleum sector, then electricity generation, which was 50.8 percent of total usage, constitutes 69 percent of usage excluding PEMEX/petroleum sector consumption.

Based on the foregoing analysis, if we assume that 69 percent of all imported natural gas is used for generation of electricity, and that Mexico will continue to increase its imports from the United States, then to the extent that clean energy replaces natural gas as a source of electricity, each additional bcfd of natural gas that would otherwise be imported could be reduced by 69 percent. This would have the effect of reducing Mexico's dependency on U.S. natural gas.

Of course, if Mexico were able to increase its domestic production of natural gas, it would not need to import as much from the United States. However, this does not appear likely. Mexico's domestic production of natural gas has been declining for many years. Under AMLO, Mexico is pursuing a state-centered energy policy that has discouraged foreign investment while at the same time providing insufficient state funding to meet oil and gas production goals. Further, Mexico to date has rejected fracking as a tool for exploration and production. Under these circumstances, Mexico will continue to be highly dependent on imports of natural gas from the United States for the foreseeable future.

Indeed, all indications are that Mexican imports of U.S. natural gas are likely to grow. The U.S. Energy Information Administration (EIA) in its Annual Energy Outlook 2020 presents a "reference case" forecast for US natural gas exports to Mexico by pipeline that shows an increase from current levels of roughly 5 bcfd up to roughly 7.3 bcfd in 2024, 7.8 bcfd in 2030, and 8.1 bcfd in 2036.

Mexican figures show potentially even higher imports. In its 2019 Report, CNH indicates that Mexico is projected to consume roughly 14.5 bcfd by 2024 based on a 2019 public consultation carried out by Mexico's National Center for Control of Natural Gas (CENAGAS). If imports continue at 67percent of total consumption, including PEMEX self-consumption, then imports in 2024 would increase to 9.7 bcfd, almost double the imports for 2019. The United States would necessarily provide substantially all these imports.

Improvement of Hydrocarbon Balance of Trade

Apart from the issue of dependency, Mexico's imports of U.S. natural gas negatively affect its hydrocarbon balance of trade. This has been an issue of particular concern to President Andrés Manuel López Obrador.

According to figures from Mexico's National Institute for Statistics and Geography (INEGI), Mexico has a substantial negative hydrocarbon balance of trade. The following table, based on those figures, shows Mexico's imports and exports of crude oil and derivatives, natural gas, and petroleum products (including gasoline, diesel, and jet fuel) for 2018 and 2019.

Mexico's Balance of Trade for Selected Petroleum Products (thousands of US dollars)

	2018	2019
Exports of Crude Oil	26,512,106	22,552,194
Exports of Natural Gas	27,990	15,319
Exports of Petroleum Derivatives	2,932,627	2,299,129
Total Exports	**29,472,723**	**24,866,642**
Imports of Natural Gas	7,325,396	6,288,056
Imports of Petroleum Products	36,858,652	32,601,253
Total Imports	**44,184,048**	**38,889,309**
Net Balance	**14,711,325**	**14,022,667**

This chart shows that both exports and imports declined from 2018 to 2019. Lower prices in 2019 for crude oil and related products, as well as lower prices for U.S. natural gas, were part of the reason for these declines. Nevertheless, the negative hydrocarbon balance of trade was very high for both years, exceeding US$14 billion in each case.

Further, since the balance of trade is in dollars, Mexico is subject to currency risk. On December 31, 2019, the Bank of Mexico exchange rate for paying obligations denominated in dollars was 18.8642 pesos to the dollar. By April 6, 2020, the value of the peso had dropped to 24.6895 to the dollar. Admittedly, the identified period is quite atypical, marked by the onset of the COVID-19 pandemic and the collapse of worldwide crude oil prices, brought on by Saudi Arabia's price war with Russia. Nevertheless, the figures still highlight the scope of the currency risk to which Mexico is subject where it has a negative hydrocarbon balance of trade, unless offset by a positive balance of trade for other products and services.

To the extent that clean energy could partially replace natural gas in future years as a source of electricity, this could help to prevent Mexico's hydrocarbon balance of trade from becoming even worse than it is now.

It is also worthy of note that with a reduction of foreign expenditures for natural gas, those expenditures could potentially be redirected to domestic purposes, i.e. for domestic employment in construction of wind and solar projects, battery installations, and transmission, and for purchase of Mexican products, equipment, and other inputs for such projects and facilities. The multiplier effect of these domestic expenditures could be significant.

Conclusion

As summarized in this paper, there are strong economic and strategic arguments for further development of renewable energy projects in Mexico. To convert those general arguments into specific projects, Mexico could carry out studies to determine the all-in costs of different scenarios for development of renewable energy plus storage projects and the scope of the corresponding benefits with respect to lower electricity prices, economic development, and job creation. The study results could then be tested in the marketplace with an appropriate bid procedure that evaluates all-in costs. Projects where benefits exceed costs should be permitted, and encouraged, to move forward.

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