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Renewable energy: the challenge of water in Mexico

Energías renovables: el desafío del agua en México

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ABSTRACT:
There is a lack of research into the way that renewable energies in Mexico can be used to address water scarcity problems. The purpose is to reveal the extent to which renewable energy can resolve the challenge of water availability and service. The PRISMA method was followed. Mexico is aware of the benefits of exploiting renewable energy sources but less cognizant of use of resources to make potable water accessible.
Keywords: Bioenergy, photovoltaics, renewable energy, water

RESUMEN:
Hay una falta de investigación sobre la forma en que las energías renovables en México se pueden utilizar para abordar los problemas de escasez de agua. El propósito es revelar hasta qué punto las energías renovables pueden resolver el desafío de la disponibilidad y el servicio del agua. Se siguió el método PRISMA. México es consciente de los beneficios de explotar las fuentes de energía renovables, pero es menos consciente del uso de los recursos para hacer accesible el agua potable.
Palabras clave: Bioenergía, energía fotovoltaica, energías renovables, agua

1. Introduction

1.1. Link between renewable energy and water resources

There is a link between renewable energy and water resources. Both energy and water are essential to survival. They play a strong role in modern economic systems as well (Hussey & Pittock, 2012). Security of supply, economic efficiency and sustainability are central to the water and energy sectors, and their survival (Hussey & Pittock, 2012). There are direct links between water and energy; there are also links between water and the development and survival of the food supply. Given that Mexico supplies much of the United States with produce, as well as feeding its own people, understanding the relationships between the water, land, energy, and even climate change are critical for practitioners in agriculture, science, and policy (Hussey & Pittock, 2012).

Water and energy are solidly intertwined. Water is used to refine gasoline, to generate electricity, to cool down nuclear power plants, and to drill oil. According to Hussey and Pittock (2012) the largest amount of water is used in the energy sector, in the production of energy. At the same time, energy is needed to get the water out of the ground, to get it to the next location, to treat it, and to pump or transport it to other areas after treatment or desalination (Hussey & Pittock, 2012). Systems that provide potable water are particularly energy-sapping. On the local level, what economists refer to as the micro level, energy is needed to heat and pump household water, including water for cleaning, showering, and hot water heating systems. The overall picture is clear: policies that make water or energy processes more efficient in one sector may actually increase demand or make other sectors less efficient (Hussey & Pittock, 2012). Throughout the globe, water consumption has become increasingly non-sustainable (Wada & Bierkens, 2014). Given the importance of water to the availability of energy, this is a critical issue.

1.2. Renewable energy and water accessibility in Mexico

Fossil fuels represent 71% of the total energy utilization in Mexico (WorldData.info, 2019). The confluence of renewable energy and water accessibility has not been achieved at any great length in Mexico. Since at least 1982, there have been studies published by researchers at the Universidad Nacional Autónoma de México in hydropower, wind, solar and biomass energy, and by researchers at the Instituto de Investigaciones Eléctricas in geothermal energy. The bulk of the Mexican research has been upon the exploitation of biomass, but far less attention, if any, has been paid to the use of biomass to fuel water production and water conveyance (Alemán-Nava et al., 2014). Biomass capabilities are just beginning to be tapped in Mexico (López Barreiro et al., 2015; Selvaratnam et al., 2015; Chen et al., 2017). Alemán-Nava et al. (2014) stated that Mexico is ranked in the top five in the world among all nations in terms of geo-thermal power generation. Despite such promise, the country has not made significant inroads into new technologies. Solar technologies have been largely ignored – even though the country is also considered among the top five in the world in terms of being an attractive investment location for projects specializing in solar technology installations.

1.3. Lack of resource utilization

Over the last 35 years, Mexico has shown that it has bountiful resources. The nation, however, lacks the will or capacity to take full advantage of its resources. If one looks at biomass conversion technologies, for instance, one finds that these technologies have grown rather dramatically over the years and were actually abundant by as early as 2000 (Demirbas, 2000). In an age when global oil reserves are rapidly being depleted courtesy of rampant demand and the steady growth of China and India (British Petroleum, 2012), nations which can offer themselves as net exporters of renewable energies stand to profit handsomely. If Mexico were able to convert their domestic economies and infrastructures in such a way as to exploit these energies for enhanced efficiency and service, they would be able to improve their economic situation. They would be able to spare themselves the continued environmental ravages that reliance upon fossil fuels invite (Manzano-Agugliaro, Hernández, & Zapata, 2010; Manzano-Agugliaro et al., 2012). Mexico, which has increasingly relied upon energy imports since the early 2000s (United States Energy Information Association, 2012), would seem particularly advantaged if they took a turn towards renewable energy as a means of bolstering water conveyance; to do so would signal a step towards the nation’s own general energy dependence.

1.4. Potential for energy utilization

Mexico has exceptional potential for geothermal energy production, particularly in the Baja area (Alemán-Nava et al., 2014). However, the high cost of investing in geothermal energy production has meant that Mexico has been unable to engage in the kind of exploration that might make it possible to harness this renewable energy source to the full. The country is presently operating one-sixth or less of its total energy-production capacity, at least when considering high and intermediate temperature hydro-thermal sources (Gutiérrez-Negrín, 2012). Hydro-thermal and geo-thermal power cannot be seriously contemplated as a corollary tool for advancing water availability across Mexico until such time as Mexico can make vital investments in the energy sector. Lack of investment is particularly ironic given that the city of Nogales has become well-known for its development of a solar-powered wastewater treatment plant (United Nations Educational, Scientific and Cultural Organization, 2014).

The Mexican government has failed over time to develop infrastructural architectures that might allow the country to exploit its extant water resources. For instance, while the southeast region of the country has 69 percent of the country's water resources, it only contributes 13 percent to the national GDP (National Water Commission, 2009). The percentage could surely be improved if the country could develop an effective renewable energy apparatus that facilitates the exportation of freshwater from the southeast throughout the rest of the country, at diminished cost. Such a revitalized conveyance system, employing renewable energy staples, could help Mexico overcome the impoverishment that frequently arises from the country having severe discrepancies between different quarters of the year when it comes to rainfall (National Water Commission, 2011). Whether or not this will ever occur remains very much to be seen. Modern Mexican history suggests that oil-related taxes account for 37 percent of the nation's federal budget, while 56.5 percent of all public investment is devoted to energy projects that ostensibly revolve around oil and petroleum production and exploitation (Alemán-Nava et al., 2014).

The Secretariat of Energy (SENER) noted that public companies in the oil and energy sectors employed roughly 250,000 workers (Diario Oficial de la Federación, 2002). Even as hydrocarbon stores become increasingly depleted in Mexico (Islas, Manzini, & Masera, 2007). Since the 1960s, Mexico has increasingly relied upon fossil fuels, causing a depletion of hydrocarbon stores inside the border (Islas et al., 2007). At the same time, Mexico has eschewed the use of traditional resource environmental solutions (RES) resources such as biomass (Secretariat of Energy, 2011a).

1.5. Strength of the oil lobby

Overall, the Mexican state faces a powerful oil lobby that is quite reluctant to see any departure from an oil-dependent national development policy. A widely viewed release by the Federal Commission of Electricity (2008) noted that, while the country ranked 13th globally in crude oil exportation, it ranked only 50th in electricity exportation at that time. Mexico remains a country very much bedevilled by a production and conveyance architecture that privileges oil, gas, and petroleum distribution and exportation.

1.6. Energy imports and exports: the status quo

In 2017, Mexico ranked 31st in global electricity exportation, with $200.7 million in exports (Workman, 2019a). Still, Mexico exports more electricity than its neighbor, the United States, which is ranked 33rd and has $184.3 million in exports. An architecture for renewable energy sources will need to be developed if the country is to use these tools to aid in future water availability projects. Mexico is responsible for .7% of the world's global electricity exports, while the United States is responsible for .6% of the exports (Workman, 2019a).

In 2019, Mexico ranked 73rd in global world crude oil imports, with $74.9 million in imports, or .01% of the total imports (Workman, 2019b). At the same time, Mexico is one of the top 15 oil exporters. Ranked 14th in the world for crude oil exports, Mexico exports $26.5 billion in crude oil annually, or 2.3% of the world's total. This amount has dropped 25.9% since 2014 (Workman, 2019c). Mexico ranks 77th in exportation of petroleum gas, representing a total export value of $39.4 million, or .02% of the world's total (Workman, 2019d). While Mexico does a large business in oil and gas, it is not headquartering to any of the country's top 25 gas and oil companies (Workman, 2019e). Mexico is one of the top 15 suppliers of crude oil to America. Mexico is the United States' third biggest supplier, with a total crude export base of $14.7 billion, or 9% of the total of the United States' crude imports. This amount caused a trade deficit for crude oil for the United States.

Mexico was the world's 22nd highest importer of coal in 2017, with an import value of $902.7 million, or .7% of the world's total (Workman, 2018a). While Mexico also exports coal, the value is low; in 2017, the export total came to 763,000. In 59th place globally, Mexico's coal exports only represent .001% of the global total (Workman, 2019f). Mexico is the 7th largest charcoal exporter, with an export value of $37.9 million as of 2017, equivalent to 3.4% of the world's product (Workman, 2018b).

1.7. Implications for government and public policy

Renewable energy and water availability are two vital areas of public policy that have not been married together in practical policy-making endeavours of the Mexican state. This is rather ironic insofar as the Mexican government has formally committed itself in this millennium to making greater use of renewable energy sources (Alemán-Nava et al., 2014). While pressure from the oil and gas sector might explain the lack of practical progress, it is also entirely possible that a lack of infrastructural resources, and expertise, is also conspiring against the federal government's ability to make good on its pledge.

2. Methodology

2.1. General literature review

This general literature review examines a wide array of scholarly literature, predominately from 2000 on. Literature dating from 2000 onward has been emphasized because recommendations and implementations need to be accomplished based on contemporary information and data. Basing recommendations on old information is counterproductive. Recent articles address challenges faced by Mexico in the current time. Moreover, more recent articles will offer a greater insight into technological innovations that can overcome the problems that may be posed while trying to make renewable energy a heuristic for bettering water access for millions of Mexicans and businesses.

A keyword search was used to find pertinent materials. Databases such as Scopus EBSCOHost and Web of Science were utilized because of their extensive holdings and strong reputations as scholarship depositories. The articles considered for inclusion were vetted for thoroughness, relevance to the situation in Mexico, for the standing of the scholars crafting them, and for the extent to which the sources in question exemplify careful primary research or are merely descriptions of research first penned elsewhere. It was desirable that the article offer a coherent and practical solution that Mexican decision-makers can press into action. Not every source used in this article offered a clear solution to the problems of Mexico and its water situation, but all of them shed light upon some action which should be undertaken if the Mexican government is sincere about using renewable energy as a tool for overcoming the country's persistent water accessibility shortfalls.

This paper furnishes a general literature review guided by a modified version of the PRISMA Statement. The assessment of each of the literature source considered whether the article provided a clear rationale and objective, the type of information it drew up, the eligibility criteria for empirical studies, bias factors, methods for collecting data, and the strength of the evidence presented in the studies that were being investigated (Moher, Liberati, Tetzlaff, & Altman, 2009). The six criteria enumerated above were used to assess the worthiness of specific literature sources. While the PRISMA method is typically used with a larger selection of literature, it provided an effective framework for inclusion.

2.2. Examples of literature utilized

A table which illustrates samples of the literary sources used in the research is provided in this section. Table 1 presents a representative, and selective, sampling of literary sources. A great many resources were consulted; thus, this table constitutes only a representative sampling. To include all of the sources from the references would be unwieldy. The majority of these sources are scholarly articles, generally the type of source material most valuable to an academic discussion of this sort. This table serves another purpose: it quickly shows that in the majority of the literature, the connection between renewable energy and water availability/dispensation was only made inferentially.

Table 1
Examples of type of literature consulted

Authors	Document type	Main findings
Alemán-Nava et al. (2014)	Journal	Mexico has increasingly become aware of manifold alternative energy sources, but lacks infrastructure and administrative capacity to implement new innovations
Ramírez Bueno and Rocha Ruiz (2016)	Journal	Mexico has, since the 1980s, been more proactive in seeking out alternative energy forms. Geothermal energy is especially promising, though there are costs and infrastructural issues associated with its harvest
Hernández-Escobedo et al.	Journal	Mexico has strong solar energy capacity but lacks a coherent strategy for optimizing its resources. There are extant resources, but also unfulfilled

(2015)		potential
Islas et al. (2007)	Journal	Suggests ways that bioenergy can be used; indicates progress on this issue, and hints at structural/practical/political considerations that might obviate full implementation
Manzano-Agugliaro et al. (2013)	Journal	Useful at inserting Mexico within a global context
Pérez-Denicia et al. (2017)	Journal	Intimation is that Mexico seemingly lacks the technocratic and infrastructural tools needed to exploit its own rich harvest of renewable energy sources
Rosas-Flores, Rosas-Flores and Fernández Zayas (2016)	Journal	Does a good job capturing how water use can be made much easier simply through relatively easy innovations that have mysteriously been overlooked by state officials
Sanders et al. (2013)	Journal	The article leads the reader to the finding that renewable energy is a rather accessible and practicable heuristic for bolstering water services in Mexico
Diario Oficial de la Federación (2008)	Legislation	A source which shows the process by which new legislation is promulgated, while also capturing the disconnect between public utterances and policy action
Diario Oficial de la Federación (2002)	Legislation	Reiterates the common theme that Mexico is aware of its energy woes, but seems reluctant to embrace renewable energy in a practical sense
ProMéxico (2012)	Government publication	Once again, reiterates the dissonance between what the Mexican government knows needs to be done, and what has been done
Federal Commission of Electricity (2008)	Government publication	Offers useful insight into state initiatives and proclamations, as well as shovel-ready projects

3. Results

3.1. Water availability

It has been recognized for quite some time that water availability is a serious concern in Mexico. A study released in 1997 found that Northern and Central Mexico covered nearly half of the national area and encompassed nearly 60 percent of the nation's population, yet this expansive region possessed less than 10 percent of the country's water resources (Merrill & Mirro, 1997). Because of the size of the region, it is easy for analysts to believe that Mexico is proactively, if not aggressively, exploring new ways of exploiting renewable energy resources to make water more available for more people in its arid densely-packed, increasingly populated northern and central regions (National Water Commission, 2010; Instituto Nacional de Estadística y Geografía, 2018). This is not the case, however. At a minimum, requiring innovations such as solar water heaters have been bandied about by Mexican scholars as means of saving energy when rendering water more potable (Rosas-Flores, Rosas-Flores, & Fernández Zayas, 2016). There is some appreciation in the literature for solar energy infrastructures and innovations (Hernández-Escobedo, Rodríguez-García, Saldaña-Flores, Fernández-García, & Manzano-Agugliaro, 2015). However, the commingling of renewable energy with water distribution/conveyances has not been made in any real, practical, sense within Mexico despite the potential such a union offers.

3.2. Mexico and power generation

Mexico stands 16th in the world in power generation, and the Federal Electric Commission (CFE) is the 6th largest power company in the world. However, less than seven percent of the country's energy production or output came from renewable energy sources; of these renewable energy sources, bioenergy and geo-thermal power appeared to be in the vanguard (Alemán-Nava et al., 2014). Exploitation of, and outputs from, renewable energy remained quite static in Mexico in the years from 2004 to 2014 (Alemán-Nava et al., 2014). The country has singularly failed to exploit the renewable energy resources in its midst. The matter is particularly distressing when one examines the biomass output of some agricultural communities in Mexico and discovers that the installations which might exploit biomass waste as a renewable energy resource have not been established, or even pursued (Valdez-Vazquez, Acevedo-Benítez, & Hernández-Santiago, 2010). Mexico must invest much more fully in its research and development capabilities. Closer ties with private entities or non-governmental organizations (NGOs), both foreign and domestics, might help allay some of the burdens associated with full-scale investment and exploitation. Overall a policy approach which seeks to create a unified amalgam of renewable energy sources harnessed with the aim of advancing the same basic goal of energy efficiency, could bear fruit for Mexico in its efforts to, among other things, meet its obligations under the Paris Treaty (Simon et al., 2018).

3.3. Legislative attempts at regulating change

Renewable energy exploitation, in addition to the discrepancy between public utterances and practical endeavours, has been marred by a federal state focus upon oil and gas reforms. For instance, The Latin American Energy Organization states quite clearly that energy sector reforms in Mexico during the 1990s focused upon the regulation of, and limited privatization of, the oil and natural gas sectors (Pistonesi, Padilla, & Chavez, 2000). More recent iterations of national energy policy have, at the least, made formal gestures in favour of a greater role for renewable energy in the Mexican energy sector – though there is an absence of specifics detailing how renewable energy can be used to bolster water availability. To be more direct, the National Development Plan in the 2006-2012 period saw more attention paid to better integrating renewable energy into the national energy production and exploitation architecture (Gobierno de los Estados Unidos Mexicanos, 2007; The World Bank, 2014). Under this plan, energy is associated with human development in accord with the United Nation's Development Programme (Klugman, 2009). The expansive vision of the National Development Plan vis-a-vis renewable energy is detailed below.

The National Development Plan encompassed three objectives with regards to renewable energy: to “balance” the national portfolio of primary resources to renewable energies in generation capacity, growing renewable energy from 23 percent to 26 percent; to publicly promote the environmentally responsible use of renewable energy sources and biofuels; and to mitigate the increase of greenhouse gas emissions between 2006-2030 (Alatorre, 2009). In the years following 2006, it seems as though Mexico has used three critical legal instruments to promote renewable energy: the Energy Reform legislation approved by the Congress of the Union (Alemán-Nava et al., 2014); the General Law for Climate Change which was adopted in May of 2012, and which stipulated that 35 percent of all energy generated in the country should come from renewable resources by the year 2024 (Renewable Energy and Energy Efficiency Partnership, 2007; Alemán-Nava et al., 2014); and the Law for the Use of Renewable Energy and Finance of the Energy Transition, modified in 2008 (Diario Oficial de la Federación, 2008). There are, however, missing details that seem to confound efforts to make formal decrees practical realities. For example, turning to the General Law for Climate Change, it is revealed that the extent or degree of contribution for each technology is never established or defined, even as the installed capacity for renewable energy sources is expected to increase incrementally each year until 2020 for geothermal, solar and wind energy (Renewable Energy Policy Network, 2013).

Turning momentarily to the 2008 Law for the Use of Renewable Energy and Finance of the Energy Transition, the law establishes the conditions for the use of renewable energy and clean technologies, with a reduction in dependence upon fossil fuels being the stated goal. Concurrently, the Law establishes a fund for the transition to clean and renewable energies and technologies, while also providing for the establishment of a Technical Committee for the administration and distribution of resources so as to advance the goals of the Strategy (Alemán-Nava et al., 2014). It is worth noting that the above-cited law has been utilized as a vital implement in the establishment of formally mandated increased ethanol use in gasoline in the states of Guadalajara, Mexico City and Monterrey by the close of 2012 (Secretariat of Energy, 2011a). Once more, though, there is no explicit mention in any of these source materials vis-a-vis the use of renewable energy as an implement for making water availability and distribution more comprehensive and effective across the breadth of Mexico. Mexico has been (at least formally and legislatively) taking the initiative in policies promoting renewable energy since at least the Rio

Conference of 1992 (International Renewable Energy Agency, 2015), but the country has simply not sufficiently translated policy aims into practical implementation.

3.4. Legislative attempts at regulating change

In 2013 and 2014, significant changes to Mexico's constitution were enacted, as well as new legislation that endeavored to establish a new national energy narrative and improved legal and political traditions. The overarching goal was to open Mexico's energy sector to an expanded market, one based on foreign investment. Unlike the Constitution in some nations, Mexico's Constitution is a strong prevailing and active document (Cossío Díaz & Cossío Barragán, 2017).

Prior to the enactment of the constitutional amendments, the Mexican Constitution provided that the government was the direct owner of oil and hydrocarbons (with the exclusion of liquid, solid, and gas forms). There was no limitation on this ownership; the ownership right of the government was inalienable, and only the government could allow any sort of pseudo ownership to appointed individuals. Although the Constitution did not reference electricity as a form of ownership, it did regulate the water that was necessary to develop the electricity. State ownership of goods, state exploitation of goods, and the ability of the government to grant concessions for use of these goods form the three elements established in the constitution prior to the latest amendments (Cossío Díaz & Cossío Barragán, 2017).

The process of amendment of the Constitution began in December 2012 when the president of Mexico established the "Pact for Mexico" which was intended to promote energy reform. The goal was to attract investment, increase investigation into new technologies, and form 'value chains.' While hydrocarbons and Petróleos Mexicanos (PEMEX) would remain owned by the government, reforms enacted in the Constitution would begin to transform PEMEX into part of the national supply chain, as well as establishing price competitions in the fields of transportation of hydrocarbons, refining, and petrochemistry (Cossío Díaz & Cossío Barragán, 2017). Eventually, a whole new pricing structure was created, and the Ministry of Energy was strengthened. The government was given two years to convert PEMEX and the Federal Electricity Commission into State run companies. Public decentralized operations relating to transportation and storage of gas and natural gas are expected to make big changes in safety and environmental protect, as well as providing a basis for cost competition that can only help the Mexican people. Goals include efficient operation, the establishment of the National Energy Control Center, and changes to the legal framework that will require the use of clean energies and the decrease of polluting emissions in the production process. Further, the goal will be to increase economic growth and percentage of gross domestic product (GDP), as well as creating 500,000 new jobs for 2018 and 2 million new jobs by 2025 (Cossío Díaz & Cossío Barragán, 2017).

3.5. Limitations of the system

In any case, careful review of the Scopus database suggests that the scientific research in Mexico, since 1982, has predominantly focused upon the use of biomass as a renewable energy (Alemán-Nava et al. (2014). There has been relatively little attention paid to the further development of hydro-power as a renewable energy resource, but this seems to largely comport with a sense that such energy technology is already well-established and quite mature and thus not requiring the same devotion or interest from the scholarly community (Alemán-Nava et al., 2014). The most recent literature, certainly by the early 2010s, largely focused upon the harnessing of wind energy. This topic of discussion did not appear in the Mexican literature until around 1994 (Alemán-Nava et al., 2014). On balance, Mexican scholarship pertaining to renewable energy is the preserve of a few elite national institutions and universities; for instance, the Universidad Nacional Autónoma de Mexico, has been the predominant institution for releasing primary studies about renewable energy, its benefits, and how it (in its various forms) can be practically implemented (Alemán-Nava et al., 2014).

Once more, though, there does appear to be a dearth of literature highlighting how renewable energy can be used to facilitate water availability and distribution across the country, as Alemán-Nava et al. (2014) intimated. The most pertinent and conspicuous literature appears to fixate upon a transition from fossil fuels to renewable energy resources for the Mexican electricity infrastructure (Vidal-Amaro & Sheinbaum-Pardo, 2018). Part of the problem seems to be that global research into renewable energy is largely the domain of a few countries, especially the United States, and this small coterie of nations seems best-positioned to practically explore how renewable energy can be used and exploited (Manzano-Agugliaro et al., 2013; Alemán-Nava et al., 2014;). The relationship between renewable energy and the challenge of water within the Mexican context seems widely unexplored. The curious lack of willingness to revisit geothermal and hydro-power with an eye towards seeing if they can be used in novel ways is doubly unfortunate since many of the domestic hydro-power installations in Mexico date back to the 1970s (Bedilion et al., 2009).

Continuing forward, power generation from renewable energy sources has increased within Mexico since the start of the 2000s, but not in an altogether impressive manner. For instance, power generation from such sources has climbed markedly from 26 terawatts in 2003 to 39 terawatts as of 2012 (Alemán-Nava et al., 2014). Yet, the contribution of renewable energy sources to the country's overall power generation has remained stagnant, hovering around a per-year average of only 16 percent (Energy Regulatory Commission, 2013). There are various possible reasons for this, ranging from poor governmental oversight and poor collaboration between levels of government to insufficient domestic resources. Another possible factor is that private concerns are not properly enlisted in the struggle to turn renewable energy into a tool that can overcome the country's water shortage issues. Until the Constitutional changes, Mexican law held that only hydro-electric projects possessing an installed capacity of no more than 30 MW were allowed to be owned by the private sector (Secretariat of Energy, 2002). Reviewing the literature, it seems clear that if the Mexican federal government would consider bolstering and incentivizing the more large-scale involvement of the private sector in hydro-electric projects aimed at facilitating and expediting water access, then perhaps the creative energies of the private sector could lead to solutions that the Mexican government itself seems unable to find. Certainly, there is a history, since at least the 1990s, of private firms being involved in the financing and generation of energy within the Mexican context – albeit under the close eye of the Mexican government (Islas and Jerónimo, 2001; Ruiz-Mendoza and Sheinbaum-Pardo, 2010). A less restrictive and more collaborative partnership could certainly spark increased research and investment at a time when it is sorely needed. With the right financial incentives, tethered to appropriate oversight, the private sector could be prompted – in this area, as in others – to come up with new and better ways of exploiting renewable energy so that water is more widely available to more Mexicans. In any event, if any advances on this front are to be made, it seems likely that they will occur in the realm of solar energy, given that Mexico is considered one of the top five countries in the world in which to invest in photovoltaic solar power projects (Secretariat of Energy, 2003; European Photovoltaic Industry Association, 2010). Still, close observers are quick to note that the country's wind power generation potential is nowhere near to being realized at present (Mexican Wind Energy Association, 2010). The new Constitution offers a window of hope into the future.

4. Conclusions

The incapacity to exploit new innovations or possibilities is very much front and center when exploring why Mexico has not coupled renewable energy with its inefficacious water distribution system. Primarily, Mexico has failed to take steps to combine different RES in such a manner as to fashion a new, sustainable energy model that de-emphasizes waning fossil fuels in favour of novel energy sources (Alemán-Nava et al., 2014). This is regrettable in light of the fact that a combination or recombination of renewable energy sources has been proposed by various scholars as a promising way of generating power (Esen, 2000; Esen and Esen, 2005; Esen, Inalli, and Esen, 2007; Esen and Yuksel, 2013), while a number of studies have illustrated that ground source heat pump systems (GSHP) and aluminum-containing SAH systems manifest great fiscal economy when juxtaposed against conventional fuels (Esen, Inalli, & Esen 2006; Ozgen, Esen, & Esen, 2009; Balbay and Esen, 2010; Alemán-Nava et al., 2014). Mexico has simply not taken the time or effort to ascertain how such novel innovations can be applied to generating greater water availability, especially the availability of potable water, within its domestic environs. Therefore, the country faces shortages that might well be mitigated with a fresh approach.

Nonetheless, there are some positive notes to be sounded. As discussed above, the country has allowed space for private investment and production. And the Congress of the Union has, in recent years, put forth the Energy Reform Law that, among other things, makes plain that, once oil revenues reach 4.7 percent of GDP based on the year 2013, these monies will be established in a long-term account that will set aside to finance projects in renewable energies (Alemán-Nava et al., 2014). Furthermore, under the leadership of President Enrique Peña Nieto, a significant increase in the number of exploitation concessions and in the number of explorations permits for geo-thermal energy occurred (Ramírez Bueno & Rocha Ruiz, 2016). Nonetheless, it must still be acknowledged that there is no indication that a percentage of any of the aforementioned accrued monies will be set aside for developing infrastructural innovations that will facilitate the use of renewable energies for water conveyance/distribution (Alemán-Nava et al., 2014). The granting of exploration permits is far removed from actual, functioning infrastructures. In that sense, the connection between renewable energy and water distribution and accessibility is still not being made.

The country of Mexico is a nation that, in many respects, lies at a crucial intersection. As discussed above, renewable energy is one means by which Mexico can potentially change its current status as a water-poor nation. Certainly, renewable energy can conceivably reduce the cost of conveying water to different regions, can offer alternatives to hydroelectric facilities, and could even allow Mexico to do more with its existing water infrastructure. But the country is marred by obvious deficits and shortcomings that will need to be overcome if renewable energy is to become the asset it should be. Still, 96.1% of the population now has improved potable water, distributed over 92.1% of the rural population and 97.2% of the urban population (CIA, 2019). Bacterial diarrhea and hepatitis A are issues in the nation due to the polluted water. There are 2,900 km of navigable rivers and costal canals, mostly connected with canals, and mostly on the east coast (CIA, 2019). The Mexican government considers the lack of unpolluted water to be a security issue for the nation; the east notwithstanding, freshwater bodies are relatively rare and are heavily polluted.

One obvious deficit still lies in the realm of research and development investment. Alemán-Nava et al. (2014) reported that Mexico has failed to consider novel renewable energy sources such as low-enthalpy geo-thermal energy or wave power. And, on those occasions when the interconnection between water (and water conveyance) and bio-fuel technology is considered, it is most manifestly done within the context of agricultural activities within Mexico (López-Díaz et al., 2018). As a result, innovations that might prove highly cost-effective and efficient vis-a-vis serving the needs of Mexican citizens have been overlooked by a nation that desperately needs to get the most possible out of all of its available resources – natural and otherwise.

The emergence of renewable energy projects in recent years does suggest that Mexico is inching towards something akin to the architecture described above (Pérez-Denicia, Fernández-Luqueño, Vilariño-Ayala, Manuel Montaño-Zetina, & Alfonso Maldonado-López, 2017). The amendments to the Constitution are a step in the right direction. In any event, the above discussion suggests the importance of close collaboration between the federal government and local or state governments, and suggests the irrepressible need for close regulation of all RES resources and infrastructures as well as the need for close partnership between the state and the private sector so that ambitious objectives for RES resources are reached.

Reviewing the available literature has led to the conclusion that the private sector must become more deeply invested in the evolution and development of RES power generation. Turning once more to Alemán-Nava et al. (2014), Mexico has historically faltered at developing RES stores because it has failed to offer compensation mechanisms that permit energy producers operating under the aforementioned self-supply scheme to sell accumulated energy surpluses to the Federal Electricity Commission at the close of the year. Similarly, (Alemán-Nava et al., 2014) maintain that institutions such as the CFE, the SENER, or the Energy Regulatory Commission (CRE) could finally start offering to private producers preferential rates vis-a-vis transmission services fees for the conveyance of renewable energy. And, as an addendum, Alemán-Nava et al. (2014) forcefully argue that businesses should have the cost of power used defrayed or minimized by taking into account the power or energy contribution made by the business entity to the national network. There are further, more specific, suggestions that might serve to expedite the maturation of the RES sector in the Mexican context.

At the close of their excellent study on renewable energy and Mexico, Alemán-Nava et al. (2014) emphasize the vital imperative of standardizing and simplifying the procedures for the contracts of interconnection so that new start-up projects can be made more facile and more easily linked to the pre-existing energy grid. They also argue for the need to promote educational, research and development initiatives with funding drawn from public and private collaborations (Alemán-Nava et al., 2014). This is perfectly consonant with the fact that Mexico risks falling further behind in a world wherein there is a growing international corpus of academic literature on renewable energy that also encompasses discussions into novel means by which renewable energy can be harnessed (Romo-Fernández, Guerrero-Bote, and Moya-Anegón, 2012). Again, this is in harmony with the changes to the Constitution.

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