The Energy-Water Nexus in Mexico

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Abstract

In many regions of Mexico, providing access to water and energy are tightly related policy problems with interwoven challenges and issues. This paper seeks to contribute to the discussion on assessing the extent and possible impacts of such an important topic by analising three case studies: Water in the energy sector in Mexico; electricity and public water consumption; and electricity and water consumption in agriculture. Each case highlights how the planning and policy approach so far has failed to consider the energy and water sectors jointly, leading to outcomes ranking from higher electricity generation costs and CO2 emissions to groundwater aquifer depletion. Despite its relevance, the energy-water nexus has not received much attention from politicians, policymakers and the public and it is safe to argue that it is not a key priority for either sector at the moment.

Key words : Energy-water nexus, Mexico, water use in the energy sector, energy use in water management.

1. Introduction

Globally, population expansion and urbanisation have put stress on both water and energy demand. Moreover, in some regions, providing access to water and energy are tightly related policy problems with interwoven challenges and issues. Despite its relevance to Mexico, the complex dynamics between water and energy have not received much attention from politicians, policymakers and the public. Moreover, the institutional frameworks and policies of both energy and water management work in a fragmented way and it is safe to argue that the water-energy nexus is not a key priority for either sector at the moment. This paper seeks to contribute to the discussion on assessing the extent and possible impacts of such an important topic.

Mexico has a land area of approximately 2 million square kilometres (km2) with diverse climatic conditions across its territory that range from very dry with high temperatures in the north to very humid with high temperatures in the south and mild temperatures in the centre and warm coasts. Mexico has a very unequal distribution on rainfall both seasonally and regionally, about 67% of rainfalls are between June and September and only a handful of Southern states, which is the less inhabited region, receive about half of total rainwater in Mexico (CONAGUA, 2018).

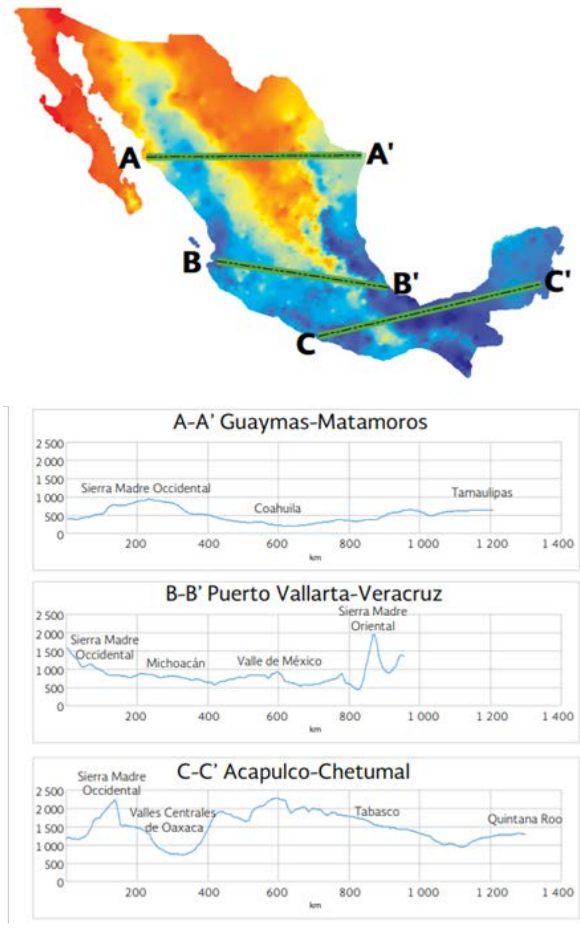

Fig. 1 - Mexico's average rainfall (1981-2010, millimetres)

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Mexico's population of 125 million is the 10th largest in the world. Mexico City, the capital, is one of the largest urban centres globally and is home to more than 20 million people, with 9 million living in Mexico City proper and more than 11 million in the 60 surrounding municipalities in the states of Mexico and Hidalgo (INEGI, 2013). Mexico is the 15th-largest economy in the world, economically comparable with Spain and Australia (WB, 2017). However, economic growth in the past year has been modest at about 2% annual average growth rate between 2000 and 2015.

All these patterns affect the way both energy and water are managed and used. Moreover, income inequality remains a challenge, as indicated by Mexico's Gini coefficient rating of 48 in 2014 (WB, 2017); 44% of the population was living in poverty in 2016 (CONEVAL, 2017). In Mexico 1.85 million people have no access to electricity, around 6 million do not have access to piped water and around 9 do not count with sewage in their households (CONAGUA, 2018).

2. Water in the energy sector in Mexico

Water is relevant across diverse stages of the energy sector in Mexico from energy production (oil and gas extraction) to the very end-user consumption (water heating for cooking or showering). Specifically, the most intensive area with the more readily available data is power generation. Water has two main uses in power generation: as a cooler in fossil fuel-fired power generation and as the main fuel in hydropower plants. In 2015, Mexico's power generation was dominated by fossil fuel with natural gas at about 60% of the total share (312 Terawatt-hour), followed by coal with 11%, oil with 10%, hydropower with 10%, wind and other renewables with 5%, and nuclear with 4%.

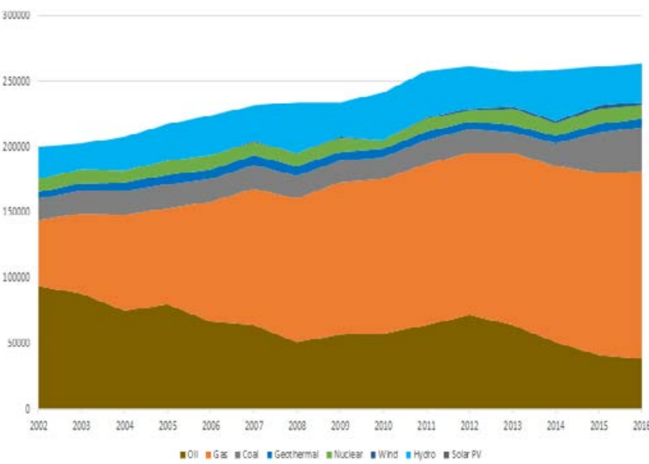


Fig. 2- Power generation in Mexico by fuel type 2002-2016, (MWh)

Mexico's National Water Commission (CONAGUA) defines hydropower as a non-consumptive use of water, as losses from leaks and evaporation are negligible. However, Mexican hydropower generation is not only susceptible to dynamic patterns on energy demand (more than doubled in the past two decades) but also to annual rain cycles. Consequently, dry years or regional draughts directly affect hydropower generation substantially.

Fossil fuel-fired power generation, which represents over 80% of the electricity generated in Mexico, requires water for their cooling systems. Despite the large share of fossil-fuel generation, water consumption dedicated to power generation other than hydroelectric is equivalent to 5% of total water consumption in Mexico, making it the third largest water consumption sector (CONAGUA, 2018). This is a relatively low share when compared to the world average (18%) or the US, where water withdrawals for thermal plants are as high as 40% of the total (USGS, 2018). This is mainly explained by the fact that coal-fired power generation requires substantially larger amounts of water for their cooling systems. In Mexico, coal-fired generation accounts for around 10% of the total, while the world's average is 38% (IEA, 2018). For instance, only the 2.7 GW Petacalco coal power plant has the right to consume more water per year than the over 150 other thermal power plants (most of them gas-fired) in Mexico altogether, which also represents 3% of total water consumption in Mexico.

Moreover, some power generation plants are located in areas with low water availability or scarcity, which has troubled both the operation and the development of new infrastructure. An extreme example of the relevance of the water-energy nexus and the tension between water scarcity and infrastructure development is the Centro Combined Cycle power plant. This 700 MW generation complex was designed to substitute aging fuel oil power plants in the area with modern combined cycle gas turbines when its construction ended in 2016. However, as of October 2018, it still is not fully operational due to the opposition of local farmers taking water for the cooling system from a neighbouring river and the failure of both parties to reach an agreement. Other groups and local media have shown similar protests and opposition to projects in which water use and energy projects are at stake, particularly in arid areas of Mexico. With more than 80% of electricity generation reliant on water for its cooling systems plus 10% for hydropower generation, water is critical for the generation of over 90% of electricity generation in Mexico. Therefore, an integrated approach for analysis, planning and decision-making process, with a particular focus on stakeholder engagement, is indispensable for the stability of the Mexican electricity system.

3. Electricity and public water consumption

The processes involved in providing water to households and establishments in cities and towns require substantial amounts of energy, namely in pumping, pipeline transportation and purifying water. After its use, significant energy is required in treating these volumes of water at sewage treatment plants. The predominant source of energy for these activities in Mexico is electricity, although some pumping stations work with diesel-fired motors.

Public water consumption is the second largest use of water In Mexico with 15% of the total, with over 12 500 cubic hectometres (hm^3) (CONAGUA, 2018). About 95% of the population has access to piped water and 93% to sewage and basic sanitation; meaning, over 6 and 9 million people have no access to these services, respectively (CONAGUA, 2018). Most of these people live in poverty in rural areas. Moreover, only 44% of water use is treated while the rest is simply by-passed in treatment plants or discharged directly to rivers, agriculture fields, lake or seas. About 57% of these non-treated volumes come from industrial users, and the rest by urban centres.

A complex legal and management framework on water use and the structure of the electricity sector have resulted in poor and ineffective water governance in Mexico. Water provision, sewage, sanitation, water treatment and billing are activities generally under responsibility of municipalities (third level of government), but there are differences depending on the legal framework of each of the 32 federal entities in which Mexico is divided. Industrial users, including mining, manufacturing and hydrocarbon extraction activities are an exception and are eligible to receive direct concessions from CONAGUA, including their responsibility for water treatment. On the other hand, most users rely on their local governments, which generally have their own municipal utility for water services. In practice, most municipal utilities have historically under delivered their responsibilities by failing to provide effective access to all consumers, having ageing infrastructure with sizeable amounts of leaks and most evidently, by not treating used water volumes.

While the poor state of the municipal utilities is a wider problem of generally weak and under budgeted institutions and the local government, there is also an important relationship with energy. The majority and in some cases, up to 80 %, of the expenses on water municipal utilities is electricity consumption. Mexico's electricity sector started a transformation from monopoly to a functional electricity market in 2014. However, state-owned electricity utility, CFE, is still the electricity provider for the vast majority of municipal water utilities, of which a sizeable number have large, long-term debts with CFE for electricity bills. Nevertheless, as CFE was, and arguably still is, not autonomous from the federal government's political decisions; it was forced to continue providing the electricity services even without receiving payment from municipal utilities. In 2017, the overall debt of municipal governments with CFE amounted around USD 2 billion (CFE, 2018). In other cases, when municipal water utilities lose electricity access for not paying their bills, they stop providing services to the public, with water treatment often first on the chopping block. Consequently, it is estimated that about 40% of total water treatment capacity remains idle or is out of service due to lack of repair or poor maintenance.

Paradoxically, the main source of revenue for these municipal utilities are water bills. However, due to a diversity of factors, varying regionally, water bills in Mexico very rarely represent real costs of all the services undertaken by utilities (extraction, transportation, purifying, sewage, treatment, infrastructure maintenance, etc.). Residential water rates in Mexico's main cities were between USD 0.09 per cubic meter (USD/m^3) to 0.81 USD/m^3 last year (CONAGUA, 2018). There is no uniform criteria for water rate calculation and they vary by municipality, legislation and utility; and in general, they are driven by political interests and isolated from technical considerations (GIZ, 2018). While the usual argument is that water subsidies are to protect the lowest-income consumers, these rates systems have actually been regressive and with poor-quality services accentuated in low-income neighbourhoods.

Without enough funds, municipal utilities continue underperforming their responsibilities and fail to perform minimum infrastructure maintenance, let alone develop new infrastructure. All this ultimately affects effective access to water services and impacts negatively on public health and ecosystems. For instance, Mexican users do not trust the quality of purified tap water, resulting in Mexico becoming the world's largest per capita consumer of bottled water in 2013 (BWR, 2014).

4. Electricity and water consumption in agriculture

While agricultural activities represent only 3.8% of GDP in Mexico, it is by far the largest water consumption sector with around 76% of total consumption (66 049 hm^3) (CONAGUA, 2018). The vast majority of water consumption in this sector is related to crop irrigation but other subsectors like cattle raising, milking and other agro-industries also claim a sizeable part of it. Out of the total water consumption in agriculture, about one third of it comes from groundwater aquifers, while the rest is surface water like lakes or rivers. Groundwater consumption in the agriculture sector is so large that it represents 27% of total water consumption in Mexico, more than the total use for public consumption, industry and power generation combined (CONAGUA, 2018). This is relevant to the energy sector, because virtually all groundwater extracted for agriculture purposes is done with electric pumps by private individuals, which consumes quite sizeable amounts of electricity.

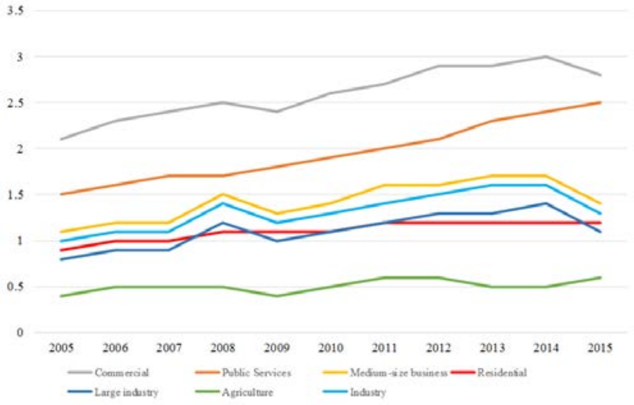
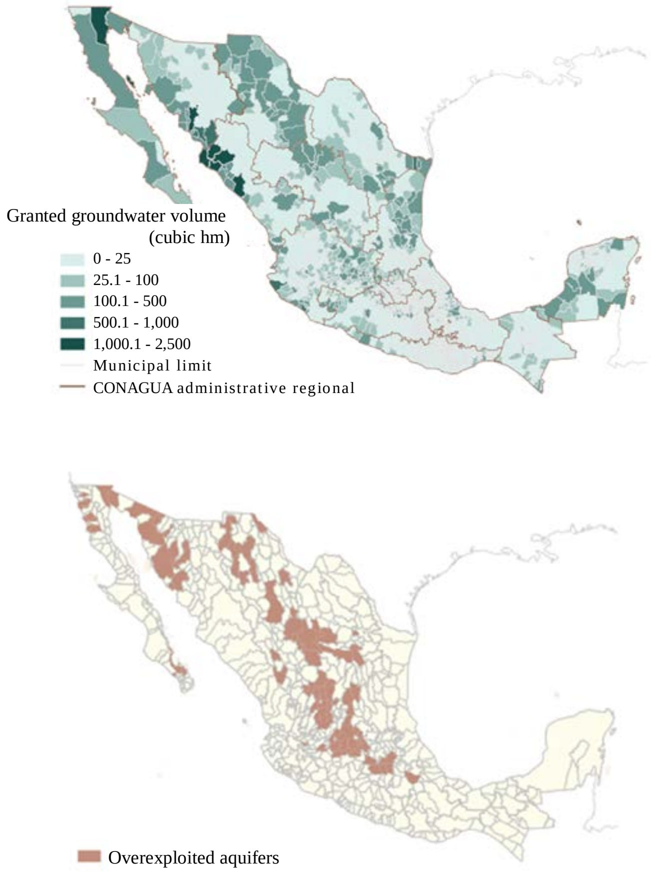


Fig. 3 - Average electricity prices by sector in Mexico

(2005-2015, MXN/KWh)

In 2016, electricity demand for groundwater pumping for agriculture alone accounted for 5.2% (11 328 GWh) of Mexico's total electricity demand (SENER, 2018). Moreover, the agriculture sector grew by 3.1% AAGR since 2006, making it the fastest growing electricity consumer sector in the last decade. The key driver of this increase is the heavily subsidised electricity rate payed by farmers. Despite energy sector reforms, CFE currently remains the only provider for energy consumers with a demand lower than 1 Megawatt, which is the case of over 95% of residential and agricultural consumers. The electricity rate for groundwater pumping in the agriculture sector has remained between USD 0.02 per kilowatt-hour (USD/KWh) and 0.03 USD/KWh in the past decade, well below all the other electricity rates payed in Mexico, as noted in Figure 2.

This artificially low electricity rate is meant to act as a stimulus for agriculture activity, especially for impoverished farmers. However, this has led to wasteful water use, especially in regions with water scarcity and highly intensive groundwater pumping for agriculture use, like in the states of Sinaloa, Guanajuato, Chihuahua and Sonora. This is particularly harmful, as 105 of Mexico's 653 aquifers are overexploited; most of them located in these four states (CONAGUA, 2018).



Fig, 4 - Mexico's groundwater agriculture extractions and overexploited aquifers.

In addition to the continued depletion of aquifers and excessive consumption of water, the subsidised electricity rate is regressive as the 33 largest users benefits by around USD 25 000 each year, whereas over 17 000 low-income farmers benefit by around USD 25 each (Avila, S. *et al.*, 2005). Therefore, the result of having a subsidy to all users of underground water pumping has been an excessive consumption of water for agriculture, overexploited aquifers, increased electricity demand at no benefit for the electricity company and thousands of dollars on tax money spent on mainly reducing costs for large farmers. Unfortunately, despite the severe environmental and budgetary consequences of this situation, it has received little political and media attention as any change to this policy will face strong resistance from farm unions and lobbyists.

5. Conclusion

These three different issues in Mexico show in different sectors and degrees the increasing interdependence of the energy-water nexus in Mexico. Each case highlights how the planning and policy approach so far has failed to consider the energy and water sectors jointly, leading to outcomes ranking from higher electricity generation costs and CO2 emissions to groundwater aquifer depletion.

In the case of electricity generation and water-use, the Mexican electricity sector is critically dependant on water consumption; therefore, a joint approach aimed at more efficient uses of water, increasing non-hydro renewable generation and a more robust transmission system could bring positive outcomes. In the second case, the combination of weak institutions at the municipal level, the reluctance of political authorities to transfer real water management costs to users and the lack of autonomy of the electricity utility (CFE) have resulted in a stalemate that results in tremendous volumes of water clean water wasted in leaks and most sewage water without treatment. Finally, in the agriculture sector, the failure to consider a joint-approach between sustainable agriculture development, water management and electricity has resulted on to the increased depletion of aquifers and increased energy demand with huge subsidies for large farmers a marginal benefit for small ones.

This brief study seeks to contribute to the debate of the relevance of the water-energy nexus in Mexico by contributing three case studies. However, other sectors left out of this paper, mainly due to lack of available data, such as oil refineries, geothermal and nuclear electricity generation and oil and gas extraction, particularly from unconventional sources, also require further analysis.

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