Analysis of Potential Energy Efficiency (EE) and Renewable Energy (RE) Opportunities in Municipal Water Utilities

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Analysis of Potential Energy Efficiency (EE) and Renewable Energy (RE) Opportunities in Municipal Water Utilities

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Report: Analysis of Potential Energy Efficiency (EE) and Renewable Energy (RE) Opportunities in Municipal Water Utilities

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Executive Summary

Water utilities in Mexico have an energy consumption of 3,969.47 million kWh per year (9,241 million pesos)—this energy consumption increases annually by 5%. For water utilities, changing the business model from investment in assets to energy services and power purchase contracts, has the potential to generate electricity savings and GHG emissions reductions.

Although there are several programs available for water utilities, there are none that focus exclusively on energy efficiency measures or renewable energy solutions. Only 4.1% of the locatable PRODDER projects and 1.3% of the locatable PROAGUA projects were energy efficiency related. Only 9 of 2,688 water utilities in Mexico had clean energy projects. Also, federal funding is available but has decreased considerably in recent years, reaching only one third of the funding seen in 2016 as shown in Section 3.

This study explores measures to optimize the demand that can have benefits and bring savings for water utilities. EE opportunities can be replicable across water utilities since technologies are commercially advanced enough and available to users. Pumping related EE solutions have great potential across all three water utilities included in the study: drinking water pumps consume at least 75% of total electricity in the facilities. Two primary RE opportunities for water utilities were identified: (1.) on-site generation (individual and aggregated) and (2.) purchasing power via Power Purchase Agreements (PPAs). In nearly all cases, the cost of the electricity procured through a PPA can be 10-30% lower than current utility rates, depending of energy volume, correlation between consumption and generation, dispersions/concentration of center loads and end user credit worthiness.

The new tariff scheme may have resulted in exponential rising costs of electricity for water utilities, but it also represents an opportunity for energy management. This strong market signal is more effective than environmental regulations to seek operational changes and reduction in energy consumption.

Public decentralized water utilities have expertise in energy management and monitoring, but usually lack funding, have superficial energy framework understanding and do not necessarily have contracting experience in the energy sector, or the faculties for investing in a PV system. New business models with low or no investment (such as a PPA) could be implemented. Water utilities need to keep up-to-date accountant books to prove their financial strength. Also, current resources from CONAGUA could be used as credit for water utilities or warranties for private developers.

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Abbreviations and Acronyms

AMD: Aguas del Municipio de Durango

ANEAS: The National Association of Water and Sanitation Companies of Mexico (Asociación Nacional de Empresas de Agua y Saneamiento de México)

BANOBRAS: National Bank of Public Works and Services (Banco Nacional de Obras y Servicios Públicos)

CAEP: Climate Action Enhancement Package

CEIA: Clean Energy Investment Accelerator

CEL: Clean Energy Certificates

CENACE: The National Energy Control Center (Centro Nacional de Control de Energía)

CEPAL: UN. Nations. Economic Commission for Latin America and the Caribbean (Comisión Económica para América Latina y el Caribe)

CESPM: Comisión Estatal de Servicios Públicos de Mexicali

CFE: Federal Electricity Commission (Comisión Federal de Energía)

CONAGUA: National Water Commission (Comisión Nacional del Agua)

CONAPO: National Population Council (Consejo Nacional de Población)

CPEUM: Political Constitution of the United Mexican States (Constitución Política de los Estados Unidos Mexicanos)

CPI: Basic Index of Prosperous Cities

DBOT: Design, Build, Operate and Transfer

DC: Direct current

DO: Dissolved oxygen

DOE: U.S. Department of Energy

DOF: Official Journal of the Federation (Diario Oficial de la Federación)

ECM: Energy conservation measures

EE: Energy Efficiency

EMS: Energy Management System

EPA: U.S. Environmental Protection Agency

EPC: Energy Performance Contracting

FONADIN: National Infrastructure Fund

GDBT: Low Voltage High Demand

GDMTH: Large Demand in Medium Hourly Voltage

GDMTO: Large Ordinary Medium Voltage Demand

GHG: Greenhouse gas emissions

HVAC: Heating, ventilation, and air conditioning

IDB: Inter-American Development Bank

IMTA: Mexican Institute of Water Technology (Instituto Mexicano de Tecnología del Agua)

INECC: Institute of Ecology and Climate Change

INEGI: The National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía)

IRR: Internal Rates of Return

IT: Information security

KWh: kilowatt-hour

LAN: National Water Law (Ley de Aguas Nacionales)

LED: Light-emitting diodes

LIE: Electricity Industry Law (Ley de la Industria Eléctrica)

MEM: Wholesale Electricity Market (Mercado Eléctrico Mayorista)

NADB: North American Development Bank

NDC: Nationally Determined Contribution

NPV: Net Present Value

NREL: National Renewable Energy Laboratory

O&M: Operations and Maintenance

OC: Basin organization

OPD: Public decentralized water utilities (Organismo Público Descentralizado)

OT: Operation technology

PBAR: Wastewater pumping facilities

PDBT: Small Demand in Low Voltage

PIGOO: Program of Management Indicators of Water Utilities (Programa de Indicadores de Gestión de Organismos Operadores)

PPA: Power Purchase Agreement

PROAGUA: Potable Water, Drainage, and Treatment Program (Programa de Agua Potable, Drenaje y Tratamiento)

PRODDER: Rights Refund Program (Programa de Devolución de Derechos)

PROMAGUA: Water Utilities Modernization Program (Programa de Modernización de Organismos Operadores de Agua)

PROSANEAR: Wastewater Sanitation Program (Programa de Saneamiento de Aguas Residuales)

PV: Solar photovoltaic

RAMT: Medium voltage agricultural irrigation

RE: Renewable Energy

RFP: Request For Proposals

RHA: Administrative Hydrological Region (Región Hidrológico-Administrativa)

SCADA: Supervisory Control and Data Acquisition

SEMARNAT: Secretariat of Environmental and Natural Resources of Mexico

SGAPDS - Sub Directorate General for Drinking Water, Drainage and Sanitation

SHCP: Secretariat of Finance and Public Credit (Secretaría de Hacienda y Crédito Público)

SIMAS: Sistema Municipal de Aguas y Saneamiento de Torreón

VAV: Variable air volume

VFD: Variable frequency drive

WU/OOA: Water utilities (Organismos Operadores de Agua)

WWTP/PTAR: Wastewater treatment facilities or plants (Plantas de Tratamiento de Agua Residual)

1. Introduction to Project

Mexico requested to NDC Partnership support to look into and review the potential of energy efficiency (EE) in municipal water pumping and water treatment infrastructure to identify their mitigation potential. This work includes among others: identify EE measures, determining where and how much energy is used; identify measures that do not involve short-term investment and those requiring technological replacement and evaluate profitability of measures; design investment projects and financing strategy.

Water utilities in Mexico face high electricity costs that can impact the provision and the quality of water and wastewater services in the country. To accelerate the implementation of strategies to achieve Mexico's NDC, the objective of this project was to provide recommendations on the RE and energy efficiency (EE) opportunities available to municipal, decentralized water utilities in the water and wastewater sectors in Mexico. Through a robust selection process (Section 4 and Appendix 1), the CEIA team partnered with three municipalities—Durango, Durango; Torreon, Coahuila Zaragoza and Mexicali, Baja California—to provide technical analysis. In Section 5, we discuss EE best practices and provide a high-level set of recommendations for the municipalities involved in this study. Further, in Section 6, we similarly discuss the RE procurement options available to the partnering municipalities.

The project focuses on technical support for renewable energy (RE) and energy efficiency (EE) in the water and wastewater sectors, specifically partnering with the operating agencies in charge of water and wastewater treatment in municipalities with populations higher than five hundred thousand inhabitants and offering analysis to help key partner municipalities move forward with RE and EE solutions for their water utilities.

With Mexico's abundant solar and wind resources, harnessing renewable energy (RE) is increasingly becoming a viable way for organizations to simultaneously reduce energy costs and dependence on fossil fuels for electricity. Declining global prices on RE components, transaction costs, national policies, and aspirational commitments aligned with the Paris Agreement, have all contributed to increase the attractiveness of RE adoption. In support of its Paris Agreement goals, Mexico established its "Energy Transition Law" with a target of generating 35% of its electricity from clean sources by 2024 (and 50% by 2050). The water and wastewater sector now have some new opportunities to take advantage of clean energy.

2. Mexico's NDC and Relevance to the Water and Wastewater Sectors

On November 4, 2016, Mexican government published a decree (Presidencia México, 2016) by means it is announced that the Paris Agreement was signed, approved by the congress, and subsequently ratified by the President of Mexico.

In 2015, the country presented its Nationally Determined Contribution (NDC) to the Secretariat of the United Nations Framework Convention on Climate Change. This First NDC (SEMARNAT, 2015) committed Mexico to reduce, in an unconditional manner, GHG emissions in 2030 by 22% below the baseline of the "business as usual" (BAU) forecasts considering 2013 as the reference year[1].

In the NDC the issue of water is indicated as a cross-cutting issue that includes, for example, productive systems in agriculture, livestock, industrial production, urban development and land use; and it is also considered in the Conservation, Restoration and Sustainable Use of Biodiversity and Ecosystem Services.

Likewise, the issue of water is influenced by energy efficiency policies that are part of the Multisectoral Approaches and Actions indicated in the NDC in the field of mitigation.

2.1 Vulnerability of the Water Sector to Climate Change

The adverse effects of climate change are strong connected to the fulfilment of some human rights like the rights to a healthy environment, health services, food and drinking water supply, decent housing and education. The protection of these rights, as well as ecosystems and biological diversity, are highly dependent on water systems and these could be influenced in turn by the extent and operations of water infrastructure and services. The link between respect for human rights, the climate action and the water resources is increasingly evident (SEMARNAT, 2020).

In a broad sense the economic development and ecosystems are in competition for limited water resources since both demand access to water in enough quality and quantity. For example, the constant increase in livestock and their products could accelerate deforestation or increase the stress and pollution of water bodies. Within this context the water supply and treatment in Mexico, provided by the public water operators, present a wide range of issues for example: non-efficient fees and tariffs systems, elevated energy costs, in some cases the use of energy-

[1] Derived from the court ruling issued by the Eleventh Collegiate Court in Administrative Matters of the First Circuit (file number 81/2021), as well as the agreement dated September 28, 2021, of the Eleventh District Court in Administrative Matters in Mexico City (file Inc. 218/2021) in relation to the suspension measures of the review of the Nationally Determined Contributions (NDC for its acronym in English) contained in the amparo filed by Greenpeace Mexico on March 9, 2021, the NDC of 2015 are currently in effect.

intensive pumps and treatment technologies or schemes in ongoing operations, the lack of energy efficiency measures and the lack of energy recovery from wastewater. All these problems affect the quality of the service.

At present day in Mexico, the availability of water is currently in danger. At least 14% of the hydrological basins are in deficit and 16% of the aquifers shows over extraction. Additionally, the coverage of the residential water supply and sanitation services is not 100 % provided. In rural areas, this percentage is lower than in urban areas, and this situation is exacerbated in marginalized areas. Social asymmetries, as well as gender inequalities, affect the accessibility of water in sufficient quantity and quality (SEMARNAT, 2020).

The vulnerability of the water sector can be considered from several perspectives, for example: climate change could induce changes in the water resources availability. Increasingly frequent extreme weather events could also weaken said infrastructure and increase of their economical vulnerability. Water treatment and supply infrastructure is also affected by economic or legal aspects like:

- The lack of regulation that allows and supports a sustainable economic operation and the reduction of Greenhouse Gases (GHG) emissions.
- The lack of resources for its expansion and operation,
- The lack of consideration of resilience in the planning and execution of water supply and treatment facilities projects,
- The high cost of energy for the operation of the infrastructure, and
- The very state of the facilities that determines their efficiency, their losses and energy consumption.

Likewise, this sector influences the vulnerability of other sectors such as agriculture and urban development. Increase in temperature and evapotranspiration in different regions of the country due to the climate change alters already the availability of this resource, and thereby alters both the demand and consumption of the resource, a lower average annual availability of water per inhabitant could be the consequence. From an energy perspective, the use of more efficient pumps, the reduction of water losses in distribution, the production of biogas and the reuse of treated water among other measures, allow not only to reduce costs but also to reduce GHG emissions. Therefore, it makes sense to examine how energy efficiency, purchase agreements or distributed generation with renewals can contribute to reduce the economic vulnerability of this sector and increase it contributions to the mitigation of GHG by reducing electricity consumption from fossil fuel sources.

2.2 Importance of Energy Efficiency and Renewable Energy for the Water and Wastewater Sectors

Within public water and wastewater services, associated electricity expenses represent between 5 and 30% of the operating budget worldwide reaching up to 40% in some cases (Feng et al, 2012, cited by Ferro & Lentini, 2015).

There is a great opportunity to reduce energy costs across the water and wastewater sector. According to a study in Latin America and the Caribbean, EE measures can reduce electricity related costs 10% to 40% for water supply services and up to 75% for wastewater treatment facilities (Plantas de Tratamiento de Agua Residual, PTAR) (United Nations World Water Assessment Programme [WWAP], 2014, cited by Ferro & Lentini, 2015).

Mexico is no exception. Water operators face high electricity costs and this cost burden has led to several service disruptions. In 2020, when water utilities in five Mexican municipalities could not pay their debts, Mexico's electricity utility, the Federal Electricity Commission (CFE), shut off their power[2]. Furthermore, in 2019, 84 municipal mayors requested Hidalgo State government support to pay for electricity bills to continue providing their populations with water services (Alcaraz, 2019).

The following study outlines EE and RE strategies that water utilities (Organismos Operadores de Agua, OOA) can undertake to complement electricity supply options, optimize their processes, and reduce costs. In addition, these strategies provide environmental benefits, aligned with the country and city-level climate change mitigation goals that have been put into place.

The creation of the Wholesale Market under the Energy Reform provided all final users to reduce their energy bill costs and lowering their carbon footprint with a whole new portfolio of opportunities[3] for both on-site generation (distributed generation: below 500 kW) and procuring clean energy from a third party (qualified supplier scheme) through a power purchase agreement. These two options will be explored further in the document for water utilities.

[2] Qro: CFE will suspend service in Amealco and affect the drinking water system (Quadratin Querétaro). May 23, 2021. See: https://agua.org.mx/tag/cfe/

[3] GIZ, SENER and CEIA has published a guidebook for procuring clean energy in Mexico that can be found: https://energypedia.info/images/7/7d/Modalidades_Compras_ER_GIZ_2018.pdf

3. Background and Key Actors in the Mexican Water and Wastewater Sectors

3.1 Water and Wastewater Sectors: Main Actors and Organizational Structure of Water Utilities

The main legal frameworks that determine water management in Mexico are the Political Constitution of the United Mexican States (CPEUM) see for example art 27 (the nation owns all national waters and assets), art. 115 (Municipalities will be in charge of public services like: water, sewage and treatment and disposal of wastewater) and the National Water Law (LAN) see for example art. 4 (CONAGUA legal attributions for administration of national waters and their public assets).

The national and state level actors responsible for dictating and coordinating municipal responsibilities, either directly or through third parties, are "Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), CONAGUA and the State Water Commissions. Each of these organizations is shown in Figure 1 and described below.

SEMARNAT works directly with the federal branch to propose bills, regulations, decrees and agreements related to the water sector. In addition, SEMARNAT issues Official Mexican Norms on water matters at the proposal of the Commission, among other activities (LAN, 1992, Article 8).

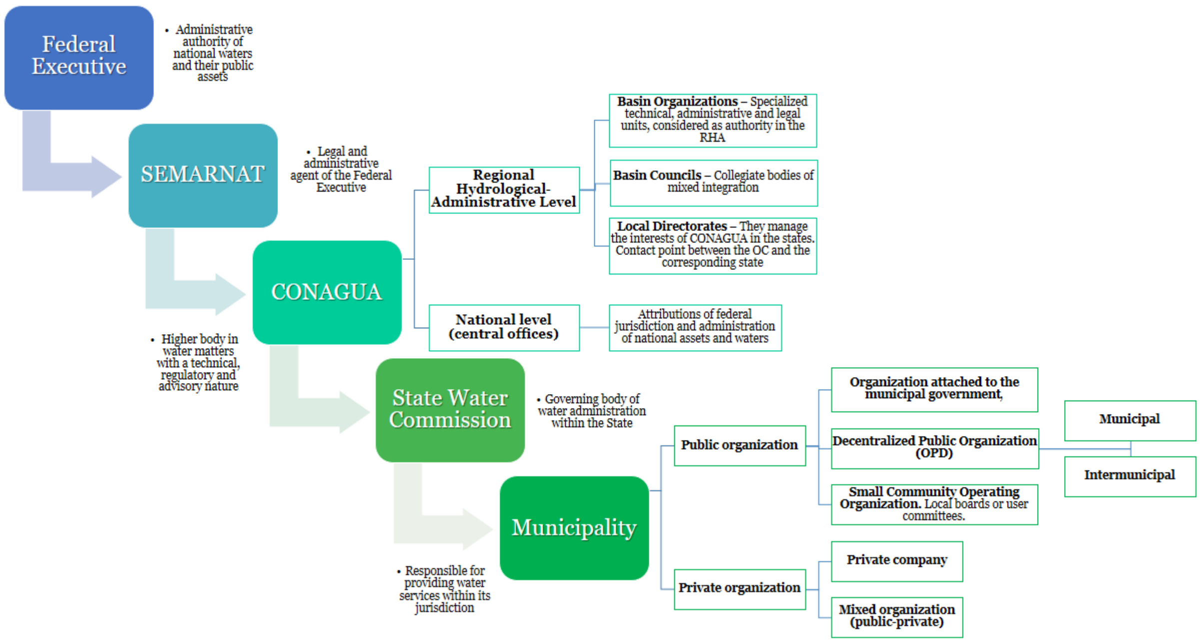
CONAGUA is a decentralized administrative agency of SEMARNAT that acts as the highest decision-making power in Mexico when it comes to the management, control, and protection of public waters. To comply with its duties, CONAGUA is divided into two different modalities at the National Level and Regional Hydrological - Administrative Level, through its Basin Organizations (Organismos de Cuenca, OC[4]) (LAN, 1992, Article 9).

- At the National Level the central offices of CONAGUA have federal-level powers (technical, normative, budgetary and consultative) and administer national waters and assets, in addition to those established in Article 9 of the LAN.
- At the Regional Hydrological - Administrative Level, the Basin Organizations help manage water resources as the technical, administrative and legal arm of CONAGUA. They work in harmony with the Basin Councils (mixed integration collegiate bodies) that consider the plurality of interests, demands and needs in the corresponding basins and with the local

[4] In Mexico, water management is distributed in territorial units known as hydrological basins (areas of the earth's surface in which water flows in different forms through a hydrographic network of watercourses that converge in a main one). These Hydrological Regions (Regiones Hidrológicas, RH) are made up of one or more basins and the Hydrological-Administrative Regions (Regiones Hidrológico-Administrativas, RHA) are made up of several Hydrological Regions. The Federal Government relies on the 13 existing Hydrological-Administrative Regions to establish water policies through the National Water Program.

Directorates that are a point of contact between the Basin Organizations and the federal entities to apply CONAGUA's policies, strategies and programs.

Figure 1. Main Actors in the Mexican Water and Wastewater Sectors.



Source: Authors with information from CONAGUA (2019f) and INEGI (2016)

A State Water Commission is a decentralized public agency within the state government, considered to be a governing body for water administration within its entity (CONAGUA, 2019f). Through State Water Laws, water planning, management and conservation is regulated. State Water Laws also outline the general terms and conditions municipalities (e.g. rate setting) must follow to provide public water and wastewater services.

To fulfill their obligations, municipalities have the option to grant a concession to a public, private or mixed organization known as a "water utility" (OOA) (Camacho & Casados, 2017). The National Institute of Statistics and Geography (INEGI) defined the classification of water utilities, "Public water utilities are attached to the municipal government (represented in drinking water and sanitation directorates and commissions) or in public decentralized water utilities (Organismos Públicos Descentralizados, OPD). In small or rural communities, water utilities are known as local boards or user committees. Less frequently, private concession companies are involved in service provision" (INEGI, 2016).

In 2014, the Water Utilities Census registered 2,688 water utilities in Mexico[5], 152 of which are managed by the private sector (concessionaires) and the remaining 2,536 water utilities are part of the public sector in its different structures. In accordance with the extent of physical coverage these water utilities are broken down as follows: 1,245 water utilities operate only at municipal capitals, 892 provided service in municipal capitals and other localities, 350 served entire municipalities and 201 provided service only in rural localities or to an entire federative entity (INEGI, 2016).

To provide services, water utilities must have a decree of creation issued by the municipal authority, under which the function of managing water resources and generating the necessary technical infrastructure is delegated. In addition, water utilities are granted authorization for the use of water and its distribution within a given geographic area (municipality, urban locality or rural locality). In the case of private companies, water concessions are granted (INEGI, 2016).

Water utilities have the necessary legal support (from the three branches of government) to join with other municipalities (forming intermunicipal bodies) and to concession water services to private companies or public-private partnerships (Camacho & Casados, 2017).

All of these mandates suggest that water utilities have decision-making power over the infrastructure they manage and, therefore, may be able to promote, manage and implement energy efficiency and renewable energy projects that help them improve their financial health by reducing costs and thus ensuring the provision of service and contributing to the reduction of GHG emissions.

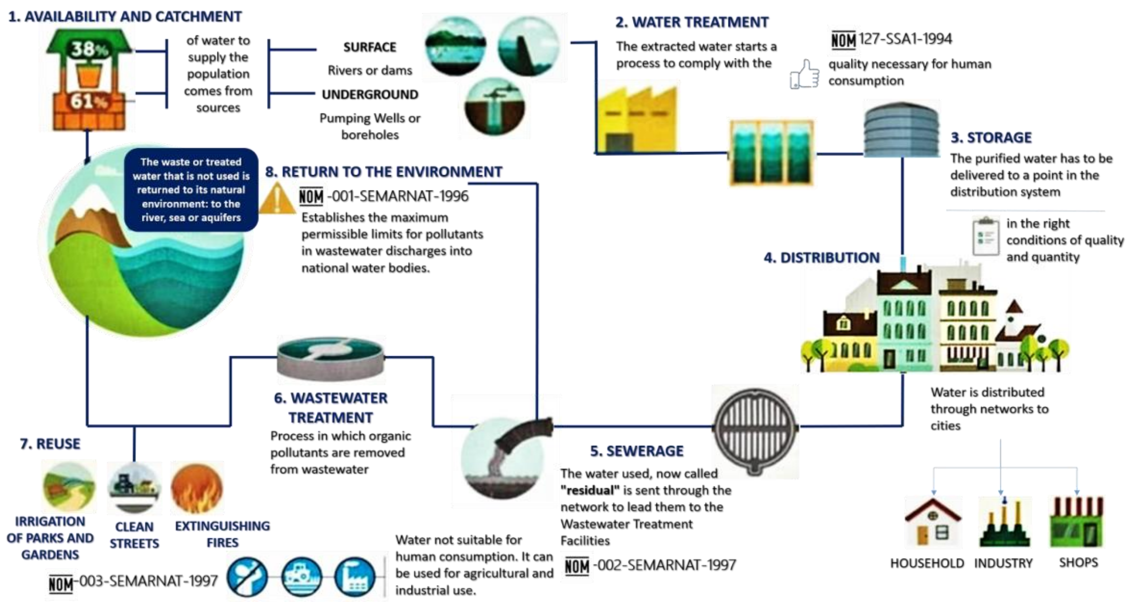
3.2 Water Utility Energy Consumption

The urban water cycle operated by a water utility consists of a series of processes. The first stage is known as "Supply", in which quality water is extracted and distributed for agricultural, industrial and domestic purposes. The second stage, known as "Sanitation", collects, treats and disposes of excess or discharged water from consumption points, known as "wastewater".

During each phase, energy is required to operate the hydraulic pumping and treatment infrastructure. To produce a certain volume of "quality water" (defined as such by the official Mexican Health and Sanitation Standards), a certain number of kilowatt-hours (kWh) is consumed, subject to site conditions. Figure 2 shows the processes of the urban water cycle with the different stages of water production and distribution.

[5] The National Hydric Program for 2020-2024 indicates that there are only 2,200 water utilities (Comisión Nacional del Agua [CONAGUA], 2020b).

Figure 2. Urban Water Cycle.



Source: *Image extracted and adapted from the document "Análisis de las Tarifas Eléctricas en los Sistemas de Agua Potable y Saneamiento de México" (El Colegio de México, 2019).*

Note: Of all the wastewater produced, only approx. 54% is collected in the sewage systems, the rest of the wastewater is discharged into the environment without treatment (SEMARNAT-INECC, 2018).

According to the 2014 United Nations report on the development of water resources globally, **the amount of energy needed to provide 1 m³ of safe water for human consumption from various water sources (surface, underground, treated water) can range between 0.37 and 8.5 kWh/m³** (WWAP, 2014).

Energy consumption at the water production and distribution stages varies considerably between countries, states, and even at the local level. This depends widely on different factors, such as the volume extracted, treated and transported, demographic, topographic, technical, hydrological factors, etc. Even climate change influences energy consumption, as water availability decreases in different regions and therefore aquifer extraction levels increasingly deepen (increasing energy consumption and related costs) (Ferro & Lentini, 2015).

Table 1 shows average data for Latin America and the Caribbean on the distribution of electricity consumption at the supply and sanitation stages (and their associated sub-stages), as well as some of the main factors that influence the amount of energy consumption.

Table 1. Energy Consumption in the Complete Cycle (Percentages)

Phase	Proportion of energy consumed throughout the cycle (%)	Comments (influencing factors)
Supply	**65% of Total**	
Raw water collection and distribution	7% (surface) to 20% (underground)	The level of extraction *depth*, the *distance* from the catchment source to the water treatment facility, the local *topography*, the design of the supply system, among others.
Water Treatment	7% (surface) to 1% (underground)	Energy consumption is determined by the volume, concentration, type of pollutants and the nature of the bacteria to be removed from the raw water. The lower the quality of the water, the higher the energy consumption for its treatment. Groundwater generally requires less treatment than surface water. Influences the desired quality for the end use (human, irrigation, industrial, etc.)
Pumping for water transport and distribution	52% (surface) to 45% (underground)	This phase is the one that demands the highest percentage of energy. Water pumping and pressurization is carried out to distribute and maintain the pressure in the network. At greater distance and altitude, transport will require more energy. It includes the transport of water to reservoirs to cushion peaks in demand. Losses in the network or water leaks increase energy intensity.
Sanitation	**35% of Total**	
Wastewater collection (sewerage)	4%	Main conditioning factors: gravity and distance
Wastewater treatment	19%	In addition to the size of the plant, the type of process and the efficiency of the equipment influence energy consumption. Processes that involve aeration require higher energy consumption.
Sludge disposal	12%	Energy can be produced in sludge treatment. Some treatment plants recover energy in the form of biogas, which reduces net consumption.

Source: Adapted from Energy Efficiency and Economic Regulation in Water and Wastewater services (Ferro & Lentini, 2015), based on Feng et al (2012) and Kenway et al (2011).

The National Association of Water and Sanitation Companies of Mexico (Asociación Nacional de Empresas de Agua y Saneamiento de México, ANEAS) indicates that electricity consumption in water systems across the country is 3,969.47 GWh per year[6] (9,241 million pesos[7]). Pumping stations alone consumed 95% (3,711 million kWh/year) of the total municipal water systems in 2019 (Pacheco, 2019a, pp 15).

3.3 Evolution of the Electricity Tariff for Water Utilities

In recent years, with the emergence of the new Energy Reform and the new tariff scheme, electricity costs have increased considerably for water utilities. The new Electricity Industry Law (Congreso de la Unión, 2014) established the basis for legal separation of generation, transmission, distribution, commercialization, and input supply activities.

Table 2.. Tariff Scheme Transition

Tariff Name	Description	Previous Tariff	Cost per energy (kWh)	Cost per demand (kW)
PDBT	Small Demand (up to 25 kW-month) in Low Voltage	2 and 6	Flat	No
GDBT	High Demand (greater than 25 kW-month) in Low Voltage	3 and 6	Flat	Yes
GDMTH	High Demand (greater than 25 kW-month) in Medium Hourly Voltage	HM, HMC and 6	Differentiated cost: base, intermediate and peak	Yes
GDMTO	High Demand (greater than 25 kW-month) in Ordinary Medium Voltage	OM and 6	Flat	Yes

Source: Authors with data from industrial tariffs from CFE (2021)

The reform of the electricity market in Mexico issued new tariff schemes, thus replacing Tariff 6 "Service for pumping water or wastewater, for public service"

[6] CONAGUA estimated in 2011 an energy consumption of 2,777 GWh for water extraction by municipalities with a extracted volume of 11.480 hm3, see chapter X. Pag. 175 (UN- CEPAL, 2018).

[7] Assuming all load centers are in medium voltage tariff: 2.5 pesos/kWh.
See: https://www.senado.gob.mx/64/gaceta_del_senado/documento/94215

which applied to water utilities, with four categories of consumption: PDBT (Small Demand in Low Voltage); GDBT (Low Voltage High Demand); GDMTH (Large Demand in Medium Hourly Voltage); and GDMTO (Large Ordinary Medium Voltage Demand), as seen in Table 2 above.

With regards to water pumping-related electricity costs, Tariff 6 included only a fixed charge (paid independently of the energy consumed) and a variable charge (based on the kWh consumed per month) through a flat cost per unit of energy (pesos/kWh). After the reform, the fixed charges changed to variable charges, per kWh of energy consumed and for capacity (per kW connected to the grid). Charges (El Colegio de México, 2019) are based on:

- Supply cost (fix charge).
- Distribution cost.
- Transmission cost.
- Cost for the operation of the National Energy Control Center (Centro Nacional de Control de Energía, CENACE).
- Two variable charges corresponding to energy and capacity (variable charge)
- Cost of the basic supplier operations.
- Cost for ancillary services no MEM.
- Costs for services related to the Wholesale Electricity Market (Mercado Eléctrico Mayorista, MEM).

Table 3 shows an example of the GDMTH tariff charges.

Table 3. Example GDMTH for CFE's North Division

Charge	Type	Units	FEB-21
Supplier (Basic Supplier)	Fixed charge	MXN/month	1,016.48
Base Energy (kWh)	Variable	MXN /kWh	0.8700
Medium Energy (kWh)	Variable	MXN/kWh	1.3671
Peak Energy (kWh)	Variable	MXN /kWh	1.5951
Distribution	Annually determined	MXN /kW	74.97
Capacity	Depends on capacity market	MXN /kW	331.00

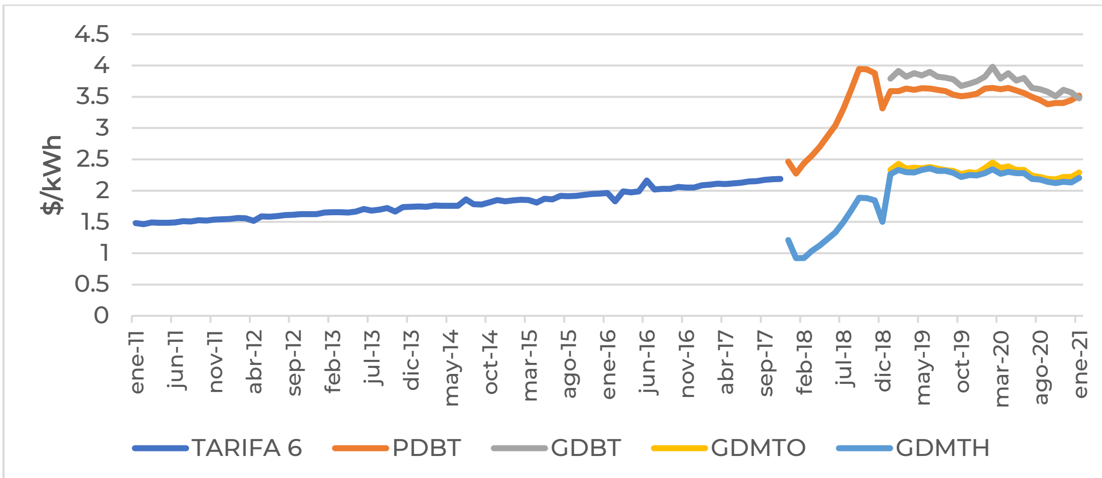
Source: Authors with data from tariffs from CFE (2021)

Notes:

- Contracted demand: should be at least 100 kW and at least 60% the total plugged capacity for GDMTH tariff.
- Base, medium and peak periods: defined in each region for different seasons of the year.

The Figure below shows the price per kWh in pesos for different tariffs, or the "energized" tariffs. This means the monomic[8] price includes the average of all charges previously mentioned on a kWh unit.

Figure 3. Monomic Price per Energy Tariff for Water Utilities After the Reform, National Averages



Source: Authors with data from: "Secretaría de Energía" [SENER] (2010), "Comisión Federal de Electricidad" [CFE] (n.d.) and "Comisión Reguladora de Energía" [CRE] (2019).

Figure 3 above also shows how kWh prices changed after 2017 when the new tariff scheme was implemented.

According to a study conducted by "El Colegio de México" (2019) commissioned by ANEAS, "*the restructuring of the tariff scheme brought about by the new energy reform placed water utilities in a vulnerable situation, adjusting to an industrial tariff without the possibility of modifying it [...] forgetting that these are organizations whose main activity is the provision of public drinking water services in municipalities*".

3.4 Impact of New Tariffs on Water Utilities

To highlight the impact that this new tariff scheme had on the operating costs of water utilities, the study from ANEAS shows that, for the municipality of Aguascalientes, the new tariff scheme increased fixed charges by 47.6%, energy charges by 72% and capacity charges by 91.9%. As of December 2017, in Monterrey,

[8] Monomic price adds all the relevant costs (energy, operation and capacity) in a certain period of time and divides against the consumed energy in that period of time.

the fixed charges brought about through the new tariff scheme increased by 62.1%. In Puerto Vallarta, the sum of fixed charges under the new applied rate (GDMTH) increased by 78% when compared to previous fixed charge payments under Tariff 6 (El Colegio de México, 2019).

One of the critical cases has been the municipality of Acapulco, which has self-sufficiency problems for the payment of energy and has been forced to request special assistance from both the state and federal governments, in order to reduce the costs of the tariff to be able to provide a continuous and quality service (Pacheco, 2019b).

While the new tariff scheme has brought about cost changes, it should be noted that the use of an hourly tariff encourages the use of energy management systems to avoid high-cost charges (to consume less energy during peak hours). Under a flat tariff rate, this behavioral shift was less possible.

As such, energy cost reduction and/or the diversification of energy sources are key points of interest for water utilities, given that, under the new tariff, energy charges can result in significant expenses that may become unpayable and therefore directly affect the continued provision of services. Now, more than ever, it is important for people to have access to water to combat the current Covid-19 health emergency.

3.5 Available Funds for Water Utilities

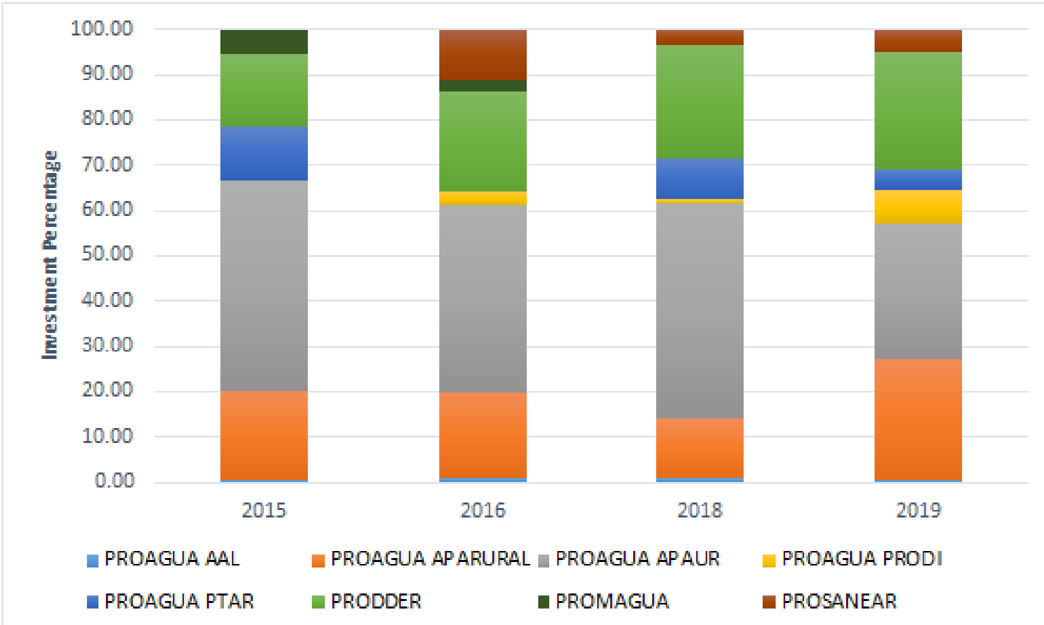
In Mexico, there are various financing programs and funds specifically dedicated to financing water and wastewater infrastructure and services. Although there are several programs available for water utilities, there are none that focus exclusively on energy efficiency measures or renewable energy solutions. The water utilities that have used funds for these types of projects have done it by their own will.

Actors across the federal, state and municipal branches, the private sector, as well as national (for example, BANOBRAS) and international banks (for example, NADB and IDB) help oversee and allocate these funds.

Of all total investments made in the sector, **80.65% of funds were provided by the Federal Government,** 11.07% by State Governments and 8.28% by Municipal Governments, and none by other actors (state commissions, loans, private initiative, etc.). In 2019, the programs that contributed the most investment resources were PRODDER with 1,691.4 million and PROAGUA (Apartado Urbano) with 1,945.6 million as seen in Figure 4 (CONAGUA, 2019d). From 2015 to 2019, FONADIN contributed in sector "water" with 1,100 billion pesos[9].

[9] Projects can be found here: https://www.fonadin.gob.mx/fni2/apoyos-autorizados/#toggle-id-3 and here: https://www.fonadin.gob.mx/proyectos-de-inversion/proyectos-apoyados/agua/

Figure 4. Evolution of Investments Percentages (%) made by CONAGUA Programs (2015-2019)



Source: Authors with data from the National Water Information System (SINA) (CONAGUA, 2019d)

The funds currently active are

- PROMAGUA (powered by FONADIN),
- PROAGUA, PRODDER and PROSANEAR (managed by CONAGUA).

These federal funds grant federal transfers or subsidies based on fiscal resources (CONAGUA) or green bons (FONADIN).

The **Water Utilities Modernization Program (Programa de Modernización de Organismos Operadores de Agua, PROMAGUA)'s** objective is to support water utilities, in order to increase the coverage, coverage quality, and improve the efficiency of their services. The National Infrastructure Fund (Fondo Nacional de Infraestructura, FONADIN) acts as the financial and private capital arm in this program to complement the non-recoverable resources granted by the program. It primarily focuses on supporting water utilities that serve municipalities with a population of more than 50,000 inhabitants or localities served by inter-municipal operators (CONAGUA, 2012b).

According to FONADIN's webpage[10], the advantages of this program are:

- FONADIN and private investors contribute 100% of the resources required for the development of the Project.
- The company that provides the service is chosen based on the offer that meets the best technical and economic conditions, increasing the socioeconomic benefit.
- The participation of FONADIN allows reducing the pressure on local public finances, favoring the financial balance of the projects and reducing the consideration that must be paid to the private investor.

The Potable Water, Drainage, and Treatment Program (Programa de Agua Potable, Drenaje y Tratamiento, PROAGUA) seeks to strengthen and increase the coverage of the water and wastewater services provided by water utilities. The program has national coverage and can be used to aid urban and rural localities for any state government that requests support. The direct beneficiaries are the state and/or municipal governments. Operationally, it is comprised by the following sub-sections: Urban (APAUR), Rural (APARURAL), Clean Water (AAL), Wastewater Treatment Facilities (PTAR), and Project for the Integral Development of Water and Sanitation Utilities (PRODI) (CONAGUA, 2020c). The PTAR subsection joined PROAGUA in 2017

The percentage of federal contribution for each project may increase based on specific considerations established by CONAGUA, including being a located in Priority Attention Zone (Zona de Atención Prioritaria, ZAP) an indigenous locality, a locality with emergency water situations, a locality in extreme poverty, with high and very high marginalization or with potable water coverage below 20%, etc (CONAGUA, 2020c).

The Rights Refund Program (Programa de Devolución de Derechos, PRODDER) provides support to projects meant to improve the efficiency and infrastructure of water and wastewater services, through resources obtained by CONAGUA from federal revenues and dues collected for use or exploitation of national waters (CONAGUA, 2016).

This program is open to all water utilities who have paid federal fees for the use or exploitation of national waters and for urban public service, with populations greater than 2,500 inhabitants. Service providers must apply for membership by submitting a Program of Actions in which they undertake to invest, together with the federal resources allocated, at least another equal amount (CONAGUA, 2016).

The Wastewater Sanitation Program (Programa de Saneamiento de Aguas Residuales, PROSANEAR) allocates federal resources, amassed from payments collected for the use or exploitation of public domain assets, such as wastewater entities. These resources are allocated towards infrastructure, operational and

[10] For more details please see: https://www.fonadin.gob.mx/fni2/wp-content/uploads/sites/3/2019/10/Lineamientos_PROMAGUA.pdf

sanitation efficiency improvements. Water utilities who have paid their fees for wastewater treatment services, and with a population of more than 10,000 inhabitants, are eligible to request membership and receive support (CONAGUA, 2018b).

Table 4 presents a summary of the main characteristics of the identified CONAGUA programs (CONAGUA, 2015) and FONADIN (FONADIN, 2019).

Table 4. Summary of Main Characteristics of CONAGUA Programs

Program (Participants involved)	Direct Beneficiaries/ Counterparty Contributing Remaining %	Actions to Support	Support Energy Projects	Non-Recoverable Support*
PROMAGUA Population greater than 50,000 inhabitants or Intermunicipal WU (CONAGUA, BANOBRAS, FONADIN, WU, and private companies in charge of DBOT-type projects.)	Water Utilities CP: Resources of the private company (generally 20% risk capital) and the rest of the private debt.	Improve physical and business efficiency through: Projects for the Comprehensive Improvement of Management, Water Supply, Sanitation and Macro-projects. Financial support for studies	Projects to save electricity and cogeneration through the use of biogas	FONADIN Resources. Up to 49% in concepts of Comprehensive Improvement of Management and Macro Projects as well as for Financial Advisory and Project Tender. Up to 50% for the preparation or updating of Studies and Strategic Consulting for the Tender and Financial Closing of the Project. Up to 75% of the cost of Diagnostic studies and Comprehensive Planning
PROAGUA Rural localities (less than 2,500 inhabitants) (SGAPDS, Executing Body, OC, DL and GPFAPS)	The executing body can be: State/State Agency, Municipality, WU or a Community Committee CP: tate, municipal, OOA, social sector, private initiative, or other entities resources	Obtainment, expansion, construction and rehabilitation of hydraulic infrastructure. Improvement of commercial, administrative and technical efficiency. Projects and studies for works	Training of personnel in Energy Efficiency (EdA); Energy Audit; Automation or replacement of pumping equipment; Evaluation, measurement and reduction of energy consumption; Reactive power reduction; Replacement or construction of storage tanks; Alternating Power Generation	Base percentage of 60% for the “new” subcomponent, 40% for “improved”, 30% for “rehabilitated” and 50% for “efficiency improvement”. It increases according to particularities and can reach up to 100% in some cases.
PROAGUA Urban Localities (2,500 inhabitants or more) (SGAPDS, Executing Body, OC, DL and GPFAPS)				Percentage varies according to the population range**. For the "new" subcomponent, base percentage is 40-70%; for "improved", "rehabilitated" and "efficiency improvement" 30-50%. Percentage increases according to particularities and can reach up to 90%
PROAGUA PRODI Population of between 50,000 and 900,000 inhabitants (SGAPDS, GFOO, SGP, GCI, SGA, OC, DL, state government,	Water Utility Public Decentralized (OPD) CP: State, municipal, OPD, and BID resources (through external credit)	Actions of the components of "Institutional Support" and "Investment in comprehensive actions" (Subcomponents: "Comprehensive Development Plans", "Comprehensive Development Actions" and	Diagnosis of energy efficiency, Acquisition and installation of equipment that reduces energy consumption, Studies for rate change and Reduction of reactive power	Base percentage of 50%, rising to 70% in case of having a comprehensive package or being a ZAP

Program (Participants involved)	Direct Beneficiaries/ Counterparty Contributing Remaining %	Actions to Support	Support Energy Projects	Non-Recoverable Support*
municipality through the OOA, AF and BID)		"Investment in infrastructure and operational improvement")		
PRODDER Population greater than 2,500 inhabitant (Water utility (public or private) and SGAPDS)	Water utility CP: State, municipal, internal cash generation resources of the service provider or loans. (They must contribute at least an amount equal to the federal contribution)	Projects for the Infrastructure of Drinking Water, Sewerage and Wastewater Treatment, for the Improvement of Efficiency and Support for Studies	Actions that ensure electricity saving and alternative energy generation actions	Up to the total amount of the rights covered, for a maximum of 50% of the total amount of the Share Program
PROSANEAR Population greater than 10,000 inhabitants (Administrative units of the RHA, SGAPDS, (GPFPAS, GFOO, CGRF and SGA) and the beneficiary)	Federal entity, municipality, parastatal, paramunicipal body and concession company CP: State, municipal, or internal cash generation resources	Sanitation infrastructure, sanitation operation and efficiency improvement	Cogeneration of electrical energy for self-consumption, Use and management of alternative energy sources for self-consumption in sanitation systems	The resources invested by the beneficiary, in proportion to the federal amount assigned, can be from 0% (for small towns) to 100%

Source: *Authors with data from CONAGUA's Programs and Operating Rules (CONAGUA 2012b), (CONAGUA, 2015), (CONAGUA, 2016), (CONAGUA, 2018b), (CONAGUA, 2020c)*

CP: Counterparty
AF - Financial Agent
BANOBRAS - National Bank of Public Works and Services
BID- Inter-American Development Bank
CGRF: General Coordination of Collection and Inspection. (SGAPDS, CONAGUA)
DBOT - Design, Build, Operate and Transfer
DL - Local Addresses. Local Management Department
EdA - Water school
FONADIN - National Infrastructure Fund
GCI - Management of International Cooperation. (SGAPDS, CONAGUA)
GFOO - Management of Strengthening of Water Utilities. (SGAPDS, CONAGUA)
GPFAPS - Management of Federal Drinking Water and Sanitation Programs. (SGAPDS, CONAGUA)
OC - Basin organization
SGA - Sub Directorate General for Administration. (CONAGUA)
SGAPDS - Sub Directorate General for Drinking Water, Drainage and Sanitation. (CONAGUA)
SGP - Sub Directorate General for Planning. (CONAGUA)
WU - Water Utility
ZAP - Priority Attention Zones
***** Federal Resources unless otherwise noted
**PROAGUA (urban localities) provides greater support to small towns (localities from 2,500 to 14,999

Energy efficiency and renewable energy-related projects are included under the efficiency improvement category in all funding programs, **which has the lowest percentage of investment across the sector**.

For example, the Budget Transparency Portal recorded that, out of 171 locatable PRODDER projects, there are only seven energy efficiency projects and one renewable energy project (SHyCP, 2020b). Out of 1,382 locatable PROAGUA projects, 18 are investment projects and assessments dedicated to energy efficiency solutions and 6 to renewable energy projects (SHyCP, 2020a).

PROMAGUA's records show that during the 2007-2012 period, the program financed a few, yet large, cogeneration projects in different wastewater treatment plants (WWTP), such as the León WWTP, El Ahogado WWTP, Atotonilco WWTP, Agua Prieta WWTP, San Pedro Mártir WWTP and Hermosillo WWTP, promoting the use of clean energy in the sanitation sub-sector (CONAGUA, 2012a).

Despite the portfolio of financing programs available to support these solutions, **few water utilities have installed renewable energy technologies for their energy consumption**. As of January 2021, only one of the 42 municipalities analyzed in this study has changed suppliers or signed a power purchase agreement (PPA) with a renewable energy generator. Table 5 below provides a summary of the water utilities that have installed clean and renewable generation systems throughout Mexico.

Table 5. Summary of Water Utilities with Clean Energy Projects

Location	Water Utility	Clean Energy Project	Resources
Guadalajara, Jalisco	SIAPA (Sistema Intermunicipal de los Servicios de Agua Potable y Alcantarillado)	1. Energy contracts with a wind power plant. 2. Cogeneration from biogas in WWTP "Agua Prieta" and "El Ahogado".	1. State and municipal resources (SIAPA) 2. PROMAGUA- FONADIN and "Consorcio Atlatec-Trident" (private resources)
León, Guanajuato	SAPAL (Sistema de Agua Potable y Alcantarillado de León)	Cogeneration from biogas in the municipal WWTP.	PROMAGUA - SAPAL and ECOSYS FYPASA (private resources)
Monterrey, Nuevo León	SADM (Servicios de Agua y Drenaje de Monterrey)	Electricity generation from biogas in WWTP "Dulces Nombres" and "Planta Norte"	SADM (State and municipal resources)
Mérida, Yucatán	JAPAY (Junta de Agua Potable y Alcantarillado de Yucatán)	Photovoltaic electricity generation in 5 WWTP.	APAZU (Potable Water, Sewerage and Sanitation Program in Urban Areas) Funds 2013 and 2014
Mexicali, Baja California	CESPM (Comisión Estatal de Servicios Públicos de Mexicali)	Photovoltaic electricity generation in WWTP Arenitas	PROSANEAR. CESPM (municipal resources) and federal resources

Location	Water Utility	Clean Energy Project	Resources
Ciudad Juárez, Chihuahua	JMAS (Junta Municipal de Agua y Saneamiento de Juárez)	Cogeneration from biogas in WWTP “Sur”	Degrémont S.A. de C.V. (private resources)
Querétaro, Querétaro	CEA (Comisión Estatal de Aguas de Querétaro)	Cogeneration from biogas	PROMAGUA. Atlatec (private resources)
San Luis Potosí, SLP	INTERAPAS	Cogeneration from biogas in WWTP “El Morro”	FYPASA (Private Resources)
Hermosillo, Sonora	Agua de Hermosillo	Cogeneration from biogas in WWTP “Hermosillo”	PROMAGUA. TIAR Hermosillo, S.A.P.I. de C.V. (Private Resources) and loans from NADB and Banco del Bajío.

Source: Authors with information from the Documentary Report of PROMAGUA 2007-2012 (CONAGUA,2012a), Situation of the Potable Water, Sewerage and Sanitation Subsector (CONAGUA, 2019h), UN-Habitat (2018a pp. 99) and information shared by CESPM and JAPAY.

WWTP: Wastewater Treatment Plant
NADB: North America Development Bank

By changing the business model from investment in assets to energy services and power purchase contracts, there is the potential to generate electricity savings and GHG emissions reductions.

3.6 Power Sector framework: alternatives for energy procurement

Mexico’s Energy Reform in 2013 created the Wholesale Electricity Market, opening to private companies to participate in segments of the energy value chain. Now private companies can participate in generation and supply of energy (commercialization). Middle to big commercial and industrial users are able to sign a Power Purchase Agreement (PPA) for energy procurement through a qualified supplier or directly through a generator. There are at least five options to reduce the carbon footprint (SENER, 2018): For the purpose of this report only three options are detailed.

On-site generation: distributed generation (up to 500 kW)

Distributed Clean Generation (DG) allows basic end users to generate renewable electricity on-site with small power plants with a capacity below 500 kW. One of the main aspects of DG is its simplicity since it does not require an energy permit from the CRE and can be installed by any type of consumer. The regulation establishes three mechanisms of compensation:

1. Net Metering that allows the netting of energy delivered to the grid and the energy purchased from the supplier, saving the regulated power tariff per kWh generated. Due to its simplicity and economic value, it is the first option to consider.
2. Net Billing: the energy purchased from the grid is invoiced with the basic supply rate, and the delivered to the network is remunerated at the Marginal Local Price (MLP) node time correspondent.
3. Total sale: applies where there is no contract Supply (energy consumption) associated with the same interconnection point of the Central Electrical. Like in net billing the remuneration is at the price of MLP.

On-site generation: above 500 kW

On-site generation above 500 kW requires an energy permit from CRE and an interconnection study done by CENACE which assess the capacity and feasibility of the grid to cope with an additional influx of energy. There are two modalities above 500 kW.

1. The Isolated Supply (IS) modality allows end users to generate or import energy for the fulfillment of their consumption, without using transmission of energy through the network public electricity. If shortages happen the end user can purchase energy and can also sell surpluses. Isolated supply has an advantage: the energy consumed in the Private Network does not pay charges for Transmission and Distribution concepts.
2. Local Generation. Similar to Isolated Supply modality, the power plant has to deliver its energy through a Private Network, but unlike IS, the end user must be a qualified user and the central electrical system belongs to a third party.

Qualified Supplier and Qualified user

Qualified users (public or private) can sign energy contracts, or Power Purchase Agreements (PPA), with a different power supplier (qualified supplier), where the tariff schemes and tariff prices differ from regulated tariffs charged by the federal utility Comisión Federal de Electricidad (CFE).

Users will usually find unregulated tariffs to be lower than regulated ones and, if requested, cleaner energy. However, certain requirements must be met, to switch from regulated user (dispatched by CFE basic supplier) to a qualified user (dispatched by a qualified supplier).

Qualified users must demand at least 1 MW. This can be achieved with only one load of 1 MW (LIE, 2014), or with several points of at least 25 kW (SENER, 2017), each when aggregated, sum up to 1 MW. In the case of public users in order to be able to aggregate several loads each of them must depend economically from the same public entity. In order to become a qualifier user, the end user must register at the Energy Regulatory Commission (CRE).

For more details and a registry guidebook see:

https://www.gob.mx/cms/uploads/attachment/file/110730/Guia_RUC.pdf

Table 6. Legal framework for Qualified Users

Topic	Publication
a) Terms to register and operate as a qualified user	DOF: 06/12/2017 http://www.dof.gob.mx/nota_detalle.php?codigo=5506927&fecha=06/12/2017 DOF: 12/07/2016 http://www.dof.gob.mx/nota_detalle.php?codigo=5444338&fecha=12/07/2016
b) Definition of demand and terms for aggregate loads within the same economic group	DOF 01/03/2017 http://www.dof.gob.mx/nota_detalle.php?codigo=5474979&fecha=01/03/2017
c) Terms for operation of the qualified user registry.	DOF 02/02/2016 http://dof.gob.mx/nota_detalle.php?codigo=5424091&fecha=02/02/2016
d) Terms for operation of the Qualified User registry (transitory)	DOF 14/04/2016 http://www.dof.gob.mx/nota_detalle.php?codigo=5423490&fecha=26/01/2016

Source: Authors with information of Comisión Reguladora de Energía

Once a user becomes a qualified user, they must choose a qualified supplier[11] (new energy provider different from current CFE basic supplier). At this moment there

[11] Qualified Suppliers require a CRE permit to provide electricity services to Qualified Users, as well as a business plan and estimated number of clients. Qualified Suppliers must also register as market participants to sell and purchase electricity in the Wholesale Electricity Market.

are 53[12] qualified suppliers (including CFE qualified supplier) active in the market that can sign an energy contract. The terms and conditions to be signed under the PPA between the new energy provider and a qualified user are negotiable: period of time for the contract, amount and type of energy (fossil, clean or mixed energy) and the price.

Advantages of becoming a qualified user: ability to choose a qualified supplier (new energy provider different from current CFE basic supplier), there is a lot of competition since, at this moment, there are 53 qualified suppliers (including CFE qualified supplier) active in the market that can sign an energy contract. The terms and conditions to be signed under the PPA between the new energy provider and a qualified user are negotiable: period of time for the contract (from short up to 3 years to long term contracts above 7 years), tailor-made contract: amount and type of energy (fossil, clean or mixed energy; potential reduction of GHG emissions) and the price (bill savings). Also, flexibility, since after the contract you can choose another qualified user.

On the other hand, disadvantages include the fact that it is an early market, therefore most of the qualified suppliers are new (except for the international corporations). Comparison among bids are not straightforward since most of them include pass through concepts where congestion is the most relevant. If the selected qualified supplier stops operating (bankruptcy) an emergency supplier will have to supply the energy at higher rates than regulated ones, forcing end users to select again another qualified supplier to avoid higher costs.

Key messages

1. The current legal framework suggests water utilities have decision-making power over the infrastructure they manage and, therefore, may be able to promote, manage and implement energy efficiency and renewable energy projects that help them improve their financial health by reducing costs and thus ensuring the provision of service and contributing to the reduction of GHG emissions.
2. The new tariff scheme has brought cost changes. For example, for the municipality of Aguascalientes, the new tariff scheme increased fixed charges by 47.6%, energy charges by 72% and capacity charges by 91.9%.
3. The use of an hourly tariff encourages the use of energy management systems to avoid high-cost charges (to consume less energy during peak hours). Under a flat tariff rate, this behavioral shift was less possible.
4. Although there are several programs available for water utilities, there are none that focus exclusively on energy efficiency measures or renewable energy solutions.

[12] https://www.cenace.gob.mx/Docs/12_REGISTRO/ListaPM/2021/03.%20Lista%20de%20Participantes%20del%20Mercado%20(Marzo-2021).pdf

5. Accordingly to the information of the Budget Transparency Portal records 0nly 4.1% of the locatable PRODDER projects and 1.3% of the locatable PROAGUA projects were energy efficiency related. Only 9 of 2,688 water utilities in Mexico had clean energy projects.
6. Despite the portfolio of financing programs available to support these solutions, few water utilities have installed renewable energy technologies for their energy consumption. As of January 2021, only 1 of the 42 municipalities analyzed in this study has changed suppliers or signed a power purchase agreement (PPA) with a renewable energy generator.
7. Changing the business model from investment in assets to energy services and power purchase contracts, has the potential to generate electricity savings and GHG emissions reductions.

4. Municipalities Selected

After a thorough analysis of key indicators presented in Appendix 1, a short list of potential partner municipalities was identified that could be strong candidates to apply or replicate RE and EE solutions in water utilities. Table 7 summaries: the selection criteria, the source of information, the indicator estimation based on the methodology of municipalities criteria identified in the Programa de Indicadores de Gestión de Organismos Operadores (PIGOO).

Table 7. Defined selection criteria, sources and indicator estimation

Selection criteria	Source	Indicator estimation
Population greater than 500k inhabitants	INEGI Census from 2010 (INEGI, 2011)	42 municipalities passed the filter
Organizational Structure (OPD)	Water Utilities Website	30 municipalities passed the filter (26 water utilities)
Renewable Energy Solutions	Table 5. (CONAGUA, 2012a); (CONAGUA, 2019g); (UN-Habitat, 2018a pp.99) and information shared by CESPM and JAPAY	Water utilities with cogeneration in their treatment facilities, with energy supply contracts, and with widely replicated RE solutions were discarded. 26 municipalities passed the filter.
Energy per inhabitant (kWh/inhab)	(CFE, 2017) and (INEGI, 2011)	The average of the values for the 26 municipalities is 23.33 kWh/inhab. Municipalities with higher and the two medium values were highly considered for the *final filter*. GHG emissions are proportional to electricity consumption.
Working relationship (%)	(IMTA, 2018) through the Programa de Indicadores de Gestión de Organismos Operadores (PIGOO)	The average of the 30 water utilities is 88.22 %
Micro-Measurement (%)	(PIGOO, 2018)	The average of the 30 water utilities is 62.67 %
Volume of Wastewater Treated (%)	(PIGOO, 2018)	The average of the 30 water utilities is 60.74%
Reported Water Coverage (%)	(PIGOO, 2018)	The average of the 30 water utilities is 96.24%
Physical Efficiency 2 (%)	(PIGOO, 2018)	The average of the 30 water utilities is 58.76%

Selection criteria	Source	Indicator estimation
Commercial Efficiency (%)	(PIGOO, 2018)	The average of the 30 water utilities is 78.60%
Overall Efficiency (%)	(PIGOO, 2018)	The average of the 30 water utilities is 45.82%

Source: Authors with information PIGOO, INEGI, IMTA, CFE, CONAGUA

The final filter splices the results of the PIGOO (http://www.pigoo.gob.mx/Inicio) indicators with the energy intensity to select the key municipalities. This filter gives special attention to energy intensity and service coverage.

To obtain the PIGOO averages, a dummy variable was used. If the utility reported data to the platform, then the utility had a 1 assigned, meaning it would be considered. Of the 42 municipalities with a population greater than 500k, only 30 were considered. From those 30 utilities, averages were calculated. The fact that some municipalities do not have values higher than the calculated average does not mean that they have a bad rating. In some cases, PIGOO rates them as outstanding or good compared to national averages.

After applying the criteria selection only 10 decentralized water utilities were pre-selected[13] (Table 8) and invited to participated via a workshop held in November 13th, 2020 where the project was presented, 7 showed interest in the project (Culiacán, Durango, Hermosillo, Irapuato, Mexicali, Morelia and Torreon). Only 4 OPD sent power data, but the maximum analysis capacity was set only for 3 water utilities, therefore the selected water utilities were Mexicali, Durango and Torreón.

[13] The cells in green color have the most desirable values, in yellow color the average values (or closest to the desirable value) and in orange color the least desirable values.

Table 8. Summary of Indicator Ratings

Municipality	State	OPD	Operating Energy Intensity per Inhabitant	Working relationship (%)	Micro-measurement (%)	Volume of wastewater treated (%)	Reported water coverage (%)	Physical efficiency 2 (%)	Commercial efficiency (%)	Overall efficiency (%)	Degree of pressure on water (CONAGUA vs AQUEDUCT)
Hermosillo	Sonora	AGUAH	121.074	75.31	57.62	61.44	98.00	53.56	67.74	36.29	Very high
Tlalnepantla de Baz	Estado de México	OPDM	51.331	94.60	93.59	2.11	99.41	45.28	61.91	76.32	High
Reynosa	Tamaulipas	COMAPA	41.045	79.17	38.10	89.83	95.36	61.42	54.74	33.62	High
Mexicali	Baja California	CESPM	33.135	96.85	91.73	97.15	98.28	81.83	99.84	81.70	High
Irapuato	Guanajuato	JAPAMI	22.311	96.04	78.84	117.23	84.00	40.88	63.75	26.06	High
Culiacán	Sinaloa	JAPAC	22.244	93.86	91.94	110.43	99.50	60.95	93.17	56.79	Very high
Morelia	Michoacán	OOAPAS	14.671	96.19	61.56	64.02	97.80	42.61	80.45	34.27	High
Durango	Durango	AMD	14.571	87.61	63.45	108.19	99.48	42.65	94.05	40.11	Medium-High
San Luis Potosí	San Luis Potosí	INTERAPAS	9.414	94.83	48.36	114.29	97.00	48.38	49.66	24.03	Medium-High
Torreón	Coahuila	SIMAS	10.861	83.80	44.24	93.69	99.00	48.96	79.41	38.88	Medium-High

Source: Authors based on data from "Instituto Mexicano de Tecnología del Agua" [IMTA] (2019), CRE (2017), INEGI (2011), CONAGUA (2019b) and World Resources Institute (WRI, 2019)

Most desirable value	Medium value	Less desirable value

.

5. Analysis of Potential Energy Efficiency (EE) Opportunities in Municipal Water Utilities

Energy efficiency opportunities in municipal water utilities can be categorized into three primary pathways:

1. Policies and incentives to promote more efficient use of water by customers;
2. Operational or process changes to save energy at treatment facilities; and
3. Technical solutions to save energy at treatment facilities.

This section presents a high-level introduction of the opportunities associated with the first two pathways, and then provides a more extensive analysis of potential technical solutions to save energy at treatment facilities. All opportunities presented are high-level best practices for municipal water utilities; some may be relevant while others may not. It is up to the utilities' operators, given their expert knowledge of their facilities and operations, to determine which opportunities may be applicable and to investigate further. Details on methods, data collection, and technical analysis are provided in Appendix 1.

Barriers towards implementation of energy efficiency opportunities do exist. These include:

- Lack of funding to invest in equipment replacement/upgrades
- Difficulties to adequately quantifying potential economic benefits of such changes, specifically those tied to benefits associated with reduced maintenance or improved reliability.
- Other barriers are associated with risk averse operations where staff are not comfortable changing treatment processes and supporting equipment which may impact water quality,
- as well as limitations to training for water and wastewater facilities' staff in operating and maintaining new equipment.

5.1 Policies and Incentives to Promote More Efficient Use of Water by Customers

Activities under this pathway include measures implemented by water and wastewater facilities or municipal stakeholders to encourage the adoption of water savings practices by end-user customers. Such actions can reduce not only the amount of potable water consumed, but also the amount of wastewater generated. These could include incentives (e.g., rebates offered for the purchase of low flow fixtures); billing structures or tariffs to discourage high water use (e.g., inverted block rate structures with increasing costs for higher usage); and/or policies or laws which allow water reuse and recycling, or which mandate efficient products.

Incentives, such as rebates, provide encouragement for customers to install water saving equipment or make water saving changes. These could include rebates that can applied towards the purchase of water saving equipment (e.g., low-flow shower heads), product giveaways (e.g., rain barrels for connecting to house gutters for the capture of rainwater, which could be used for gardening or car-washing), or financial incentives for certain modifications (e.g., installing xeriscaping[14], for instance).

Water rate billing can be structured in a way to disincentivize customers to use high amounts of water. Tiered pricing is one such example. Low rates are charged for water use on a pre-set basis (twice monthly in Mexico) below a certain threshold. Then increasing rates are charged for usage above that threshold, but below the next highest threshold, and so on with increasing rates. Water rate billing structures that are the opposite (lower costs for higher water consumption) are essentially incentivizing high water usage. Changing water tariffs requires legal and organizational procedures that may be difficult to execute, and it should also be considered that increasing water tariffs may have social and political impacts, but if done properly they can be used to encourage reduced water usage, thus resulting in cost savings.

Policies or laws that mandate the sale of exclusively water-efficient products or that enable certain behaviors (water reuse or rainwater catchment, for example) are other methods to support water use reduction. Low-flow fixture (toilets, urinals, showerheads, and faucets) requirements can ensure that only the most efficient products are available for purchase. Building or plumbing codes can help support water use efficiency and water reuse, such as codes that specify maximum pipe size or that allow for double-pipe systems (one for potable and one for recycled water). Policies that incentivize inspectors to hold violators accountable is an important component of the effectiveness of such policies as well.

[14] Xeriscaping is the process of landscaping, or gardening, that reduces or eliminates the need for irrigation. It is promoted in regions that do not have accessible, plentiful, or reliable supplies of fresh water and is gaining acceptance in other regions as access to irrigation water is becoming limited; though it is not limited to such climates. https://en.wikipedia.org/wiki/Xeriscaping

5.2 Operational or Process Changes to Save Energy at Treatment Facilities

This pathway focuses on solutions for supply side optimization, and does not generally require the implementation of new technological solutions but rather focuses on operational or process changes within a water treatment facility. It includes the creation and implementation of comprehensive operations and maintenance (O&M) protocols, in order to have a diagnostic of the initial state of the situation and be able to identify solutions in early stages. While O&M plans and strategies vary by project and application, “proper maintenance is essential to maximizing the environmental, social, and economic benefits of green infrastructure, as well as ensuring that projects perform as they were designed to.”[15]

It often also includes establishing new capital replacement processes to ensure the optimal performance of existing equipment as well as the timely replacement of components at end of life, with the most optimally efficient available.

Another action could be the implementation of supervisory control and data acquisition (SCADA) systems, which track energy use at the component/equipment level. SCADA monitoring enables the operator to closely track energy consumption and identify potential operational issues or opportunities. In addition to SCADA systems, submetering can be used to identify and track the most energy intensive processes.

Utility bill analysis can be conducted to determine if the current utility rate is the most appropriate for the site’s operations or if a different rate may be more economically advantageous. Utility bill analysis is also important for understanding on and off-peak rate periods, and when combined with hourly load data, can be used to identify potential savings opportunities (e.g., for shifting pumping loads to off-peak times, registering as a qualified user and contracting with a qualified supplier for a less expensive electricity procurement mechanism, etc.).

Leak detection in water lines saves otherwise wasted, treated water. Elimination of infiltration/inflow into wastewater lines helps ensure groundwater and rainfall don’t leak into a sewer system and increase pumping and treatment loads.

Energy demand management can be accomplished by the addition of water storage capacity or distributed energy resources (such as onsite energy generation and/or battery energy storage systems). More information on renewable energy systems is provided in *Section 6. Analysis of Potential Renewable Energy (RE) Opportunities in Municipal Water Utilities* of this report.

[15] See: https://www.epa.gov/sites/production/files/2015-04/documents/green_infrastructure-om_report.pdf

Table 9. Probable cost and benefits of operational saving measures

Measures	Probable Cost	Probable Savings and Benefits
Operations and maintenance (O&M) protocols	Low	Medium (5-20%)[16]
New capital replacement processes	High	High
Supervisory control and data acquisition (SCADA) systems	High	High
Utility bill analysis	Low	Low-Medium
Leak detection	Medium	Medium
Energy demand management	Low-Medium	Medium

Source: Authors

5.3 Technical Solutions to Save Energy at Treatment Facilities

Technical solutions to reduce energy use in water treatment plants are the focus of this study. Savings opportunities associated with these technical solutions can be categorized by loads: building loads and process loads.

Building savings opportunities include measures associated with heating, ventilation, and air conditioning (HVAC) systems, lighting, plug loads, and building envelope. Process loads are those associated with water and wastewater treatment processes. In general, building-related loads tend to be a small percentage of water treatment plants total energy use.

Power Quality Issues at the site- or facility-level can impact electrical usage and associated fees as well as equipment performance. A Technical Guideline of CFE [17] (CFE, 2009) requires at least a power factor of 0.90 (90%)[18] lagging. Power factor is provided on CFE bills.

If a site has a power factor lower than 90%, consider installing capacitors on transformers' load sides. In addition, if there are significant electrical harmonics,

[16] See: https://lapem.cfe.gob.mx/normas/pdfs/c/l0000-70.pdf

[17] See: https://lapem.cfe.gob.mx/normas/pdfs/c/l0000-70.pdf

[18] Refers to "Sag" Sudden decrease in supply voltage to a value between 0.9 p.u. and 0.1 p.u. of the nominal value of said supply voltage; followed by a voltage recovery after a short period of between one cycle at system frequency and 1 min. Indicated respectively in Table 1 to Table 3 - Power quality parameters - Typical values in medium voltage nodes (13, 2 to 34.5 kV); Typical values in high voltage nodes (69 to 138 kV); Typical values in extra high voltage nodes (161 to 400 kV). For more information on the importance of power factor in costs and energy savings, we recommend: "Power factor correction: A guide for the plant engineer. See: https://www.eaton.com/content/dam/eaton/products/low-voltage-power-distribution-controls-systems/power-factor-corrections/portfolio/eaton-pfc-guide-plant-engineer-SA02607001E.pdf

then a reactor may be required to stabilize the power. In sites where the power factor is under 90%, consider performing an assessment to determine the feasibility of improving power factor quality and to quantify benefits such as a reduction of your utility bill due to a reduction in load currents and a reduction in maintenance costs as the life of the equipment is likely to increase. In general, reactive power compensation tends to have a positive impact in your distribution system and a short payback period.

Building-focused technical solutions for energy savings are those traditionally targeted within the buildings sector: Heating, Ventilation, and Air Conditioning (HVAC) measures, lighting upgrades, plug load management, and building envelope improvement. Water savings measures will also reduce energy use and so these measures should be included as well.

Potential, low-cost HVAC measures include:

- Reduce outside airflow rates to ASHRAE 62.1-2019.[19]
- Implement an HVAC system night setback schedule.
- Monitor exhaust fan controls.
- Convert constant volume system to a variable air volume (VAV) system.
- Verify proper operation of air dampers.
- Eliminate duct leakage.
- Change setpoints to be 68°F (20°C) for heating and 75°F (23-24°C) for cooling.
- Ensuring energy- and water- consuming systems meet applicable CONUEE standards will also help to reduce energy usage.[20]

Lighting opportunities include upgrading to more efficient bulbs, ballasts, and controls as needed. All T-12 lights should be upgraded with T-8, T-5, or LED lighting systems. Other low-cost lighting measures include the replacement of standard (incandescent or compact fluorescent) exit signs with LED exit signs; the installation of occupancy sensors in bathrooms, conference rooms, and private offices; and the reduction of lighting levels in over lit spaces. Water treatment plants usually have significant exterior lighting loads. LED lighting systems are the most efficient solution for exterior lighting. Solar lighting systems are also a good exterior lighting solution.

Plug loads are those loads associated with any equipment plugged into a building. These include computers, printers, space heaters or air conditioners, refrigerators, microwaves, and snack and drink vending machines. Computer power management – ensuring computers go to sleep and/or shutdown when

[19] ANSI/ASHRAE Standard 62.1-2019 Ventilation for Acceptable Indoor Air Quality https://www.ashrae.org/technical-resources/bookstore/standards-62-1-62-2
[20] See: https://www.gob.mx/conuee

not in use – combined with laptop computers and the replacement of personal printers with network printers – can provide significant savings. Ensuring all appliances are the most efficient available and installing vending machine misers[21] on all vending machines are two additional ways to reduce energy use.

The building envelope encompasses the building systems that make up the structure's exterior walls, windows, doors, and roofs. Buildings shall be constructed or retrofitted in accordance with the to meet CONUEE (Comision Nacional para el Uso Eficiente de la Energia) standard NOM 008 ENER 2001 "Energy Efficiency in Buildings, Envelope of Non-Residential Buildings" at a minimum. Improving the building envelope beyond this standard can further reduce the energy usage. Sealing areas of air leakage (infiltration) and adding interior or exterior shading on south-facing facades are relatively easy, low-cost measures that can have significant savings. Replacing old or single pane windows with new, efficient window systems, or adding a window film, can also help improve the building envelope. Improving wall and roof insulation can reduce the amount of heat transfer, as can installing a white or light-colored roof or a green (living) roof.

Process load savings opportunities are those associated with the provision of treated water. These include all related processes at water and wastewater treatment plants, as well as electric loads associated with moving water. Generally, for water treatment plants, pumping loads (for moving raw water or distributing treated water) are the largest energy consumer, while for wastewater treatment plants secondary and tertiary treatment (including motors for aeration) dominate the energy use, see next table.

Table 10. Example of energy consumption distribution of a water treatment plant

Process of water treatment plant	Annual consumption (%)
Pretreatment	0.36%
Pumping	18.20%
Blowers	76.37%
Chillers	2.55%
Chlorination	2.28%
Building (office)	0.10%
Lab	0.10%
Workshop	0.03%

[21] A vending machine miser is an energy saving device with a motion and temperature sensor that plugs into an electric socket, and into which vending machines are plugged. The vending machine then turns on and off to both maintain products at the right temperature, and when a customer approaches. See: https://www.cleanenergyresourceteams.org/vendingmisers-refreshing-approach-energy-savings-city-saint-paul.
External Energy Misers use a controller and a machine or wall-mounted sensor to monitor room occupancy and temperature. If 15 minutes pass without any pedestrian traffic, the Energy Miser will power down the machine. The machine is powered back up when people return and at regular intervals to keep the product cold. External controllers are best suited for low traffic areas.

Source: Authors with data from Aguas Municipales de Durango

Since water pumping is such a large component of electrical demand in water treatment plant operations, incorporating efficient pumping systems into operations has the potential to result in significant savings. Begin by right sizing all pumps and motors. Additionally, **replacing all standard efficiency motors with premium-efficiency motors can reduce energy use by as much as 10%.**

Based solely on energy savings, some industrial plants may find it cost-effective to **retrofit operable standard efficiency motors with premium efficiency units**. Assuming electric rates of $0.08 USD/kWh (1.6 MXN/kWh) and comparing standard efficiency motor (92% efficiency) to a premium efficiency motor (95.5% efficiency) at the 75% load point, the simple payback period for a 75 horsepower (hp) totally enclosed fan cooled motor with an initial purchase cost of $4,640 USD is a little more than four years (annual savings of 13,373 kWh/year).

This shows that a small increase in motor efficiency can significantly reduce the energy usage. (U.S. Department of Energy [DOE], 2014)[22].

Note: if electricity costs are more than $0.08/kWh (1.6 MXN/kWh) *(currently the three municipalities included in this study pay between 2 MXN/kWh to 3.5 MXN/kWh)*, or if rebates are available to reduce the motor costs, economics would be improved. If motors are at end of life and premium efficiency is specified, the added cost will be shortly recovered in savings.

Note that although electric efficiency gains can be achieved simply by replacing individual motors, “greater efficiency gains typically can be achieved through system efficiency measures that improve the efficiency of a pump/motor system or a group of pumps/motors as a whole” (Pabie & Reekie, 2013)[23].

Adding Variable Frequency Drives (VFDs) to any AC motors (in either water or wastewater treatment applications) which can be ramped up or down for different load requirements, has significant savings potential. VFDs permit systems to operate along a continuum of power, replacing the simple binary of “on” or “off”. **With a VFD, if the motor speed is reduced to 50% of full load speed, power usage is reduced to only 12.5% of that of a full load.** Also, VFDs can be utilized to reduce peak demand which, in turn, reduces the demand charges water utilities have to pay. VFDs should be added only after right-sizing blowers and motors, to ensure the VFD used is of the correct size.

In wastewater treatment operations, right-sizing all blowers and motors and replacing them with updated, premium efficiency models can reap significant savings. In one example, by installing new energy-efficient blowers in its first-stage

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[22] See: https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf

[23] See: https://www.sciencetheearth.com/uploads/2/4/6/5/24658156/electricity_use_and_management_in_the_municipal_water_supply_and_wastewater_industries.pdf

aeration system a wastewater treatment plant in Wisconsin reduced its electricity consumption by 50 percent (U.S. Environmental Protection Agency [EPA], 2013)[24].

Advanced aeration technologies, like the one in the Wisconsin plant mentioned in the paragraph above, reduce blower energy use through the use of mechanisms such as: diffused air systems, fine pore diffusers, membrane diffuser panels, submerged turbine injectors, and high-speed turbo blowers. Automated dissolved oxygen (DO) control systems and DO sensor technology enable the aeration system to be automatically controlled to maintain a set DO level, and the blower's flow and pressure can vary constantly. Without automated controls, systems are manually controlled, and often blowers operate at constant flow and pressure at all times, regardless of whether such levels are optimal for a given moment's conditions. Such inefficiencies can lead to higher electricity costs.

In water systems the addition of water storage capacity to the system can help reduce operational costs and provide improved resilience. Furthermore, if storage capacity can be added at an elevation above the distribution network and load centers, pumping energy can be replaced by gravity fed systems. In such configurations, savings can be realized by treating and pumping water at times of reduced electrical rates (assuming a time of use rate structure is in place) or at times of excess renewable energy production. Another potential solution could be PV-powered direct-current (DC) pumping. Additionally, in the event of disruptions to the electricity grid or the water treatment plant, the water in the tank can be distributed without power.

5.4 Energy Efficiency Opportunities in Mexicali

The Mexicali's water and wastewater services public agency has a total of 122 water and wastewater-associated consumption (load) centers, 50 of which support the provision of drinking (potable) water and 72 of which support wastewater treatment. Despite the variance in number of consumption centers between water and wastewater operations, combined they each utilized nearly the same amount of energy and accrued similar costs in 2019. Table 11, below, provides a summary of annual energy use and associated costs for Mexicali.

[24] See: https://www.epa.gov/sites/production/files/2015-08/documents/wastewater-guide.pdf

Table 11. Mexicali Annual Energy Use and Costs[25]

WATER & WASTEWATER TOTAL CONSUMPTION CENTERS	122
Energy Use (kWh/year)	48,086,699
Energy Cost ($/year) WITHOUT / VAT [MXN pesos]	$76,166,773.08
DRINKING WATER CONSUMPTION CENTERS	50
Drinking volume capacity (liters per second) (2019) (drinking volume produced) (liters per second) (2019)	5,720 (3,123)
Drinking volume produced (m3) (2019)	89,049,902
Number of facilities (Nov 19-Oct 20)	50
Energy Use (kWh/year)	24,037,324
Energy Cost without / VAT [MXN pesos/year]	$38,313,886.12
MXN per kWh for drinking water ($/kWh)	$1.59
Energy use per drinking volume produced (kWh/m^3)	0.269930943
WASTEWATER CONSUMPTION CENTERS	72
Wastewater treatment capacity (liters per second) (2019)	1845.2
Wastewater treated volume (m3) (2019)	67,151,461
Number of facilities (Nov 19-Oct 20)	72
Energy Use (kWh/year)	24,049,375
Energy Cost ($/year) without / VAT [MXN pesos]	$37,852,886.96
MXN per kWh for treated water ($/kWh)	$1.57
Energy use per treated volume produced (kWh/m^3)	0.358136288

Source: Authors with data from Comisión Estatal de Servicios Públicos de Mexicali (CESPM), (CONAGUA, 2019i)

Comisión Estatal de Servicios Públicos de Mexicali (CESPM) is the city of Mexicali's public agency that provides water and wastewater services. CESPM asked that this analysis focus on the ten facilities with the highest energy consumption and provide recommendations to reduce energy usage. The ten facilities with the

[25] Calculations completed by report authors, data provided by Mexicali State Public Services Commission (CESPM)

highest energy consumption are: Planta Pot 1 (Water Treatment Plant No. 1), Planta Pot 2 (Water Treatment Plant No. 2), Planta Pot (PPOT) 3 (Water Treatment Plant No. 3), Planta Pot GPE Victoria (KM43) (Water Treatment Plant “GPE. Victoria”), PBAR-1 (Wastewater Pumping Plant No. 1), PBAR-3 (Wastewater Pumping Plant No. 3), PBAR-4 (Wastewater Pumping Plant No. 4), PBAR-10 (Wastewater Pumping Plant No. 10), PTAR-Las Arenitas (Las Arenitas Wastewater Treatment Plant), and PTAR-Zaragoza + PBAR-8 (Zaragoza Wastewater Treatment Plant + Wastewater Pumping Plant No. 8).

Current Best Practices:

Previous energy efficiency projects have been implemented at several facilities, sometimes rendering significant savings. One such example was the replacement of 32 pumps with high efficiency pumps (between 2014 and 2020), resulting in a reported 12% reduction in energy usage. The current practice is to replace pumps at end of life or with minimal life remaining with new pumps that are at minimum 10% more efficient.

Another best practice is that, based on the information provided, it appears that all motors have motor starters in a motor control center at each site, which reduces the inrush current when a motor starts and provides one location for oversight of all motor operations. One additional best practice is that currently, 80% of the wastewater treated in Mexicali is reused for non-potable applications. Driving some of these current and future best practices was the creation by CESPM in 2019 of a division for Energy Control and Renewable Energies to help centralize efforts in reducing energy use and producing onsite renewable energy.

Planned future activities include rehabilitation of the aeration system at PTAR-Zaragoza, which is expected to yield 20% energy savings. Similar savings are expected for the PTAR-Las Arenitas expansion where the expanded capacity will implement a similar design.

Energy Savings Opportunities:

On average, pumps consume 75-90% of the total energy used across all 122 water and wastewater treatment consumption centers. Therefore, energy conservation measures (ECMs) and operational modifications, such as those listed below, associated with pumps may have the most potential for savings.

Savings Opportunities for Water Pumping Stations, Wastewater Pumping Stations and Wastewater Treatment Facilities:

1. Compare cost of adding Variable Frequency Drives (VFDs) to pumps versus the expected energy savings for each pump to determine payback.

2. **Explore replacing smaller motors** (less than 2 horsepower (hp) depending on availability) with ECM (electronically commutated motor) motors.

3. **Review control sequences and the staging of pumps** to determine if a more energy efficient configuration is practicable.

4. **Update all interior and exterior lighting to LED**, focusing on sites that have incandescent or older, inefficient fluorescent lighting (e.g., T-12). Also focus on sites with higher-than-average lighting use. For instance, lighting currently uses 4.04% of Planta Pot GPE Victoria's total energy usage, which is the highest percent attributed to lighting of any of Mexicali's top ten consumption centers, which consume on average 1.87% for lighting. Similarly, PBAR-3 lighting currently uses 2.87% of the total energy usage and PTAR-Arenitas lighting uses 2.67% of the total energy use, both above the average.

5. **Consider installing capacitors on transformers' load sides in sites with low power factors (i.e., lower than 90%).** In addition, if there are significant electrical harmonics, then a reactor (coil) may be required to stabilize the power. Although the current power factor PTAR-Zaragoza + PBAR-8 and other sites almost meets the utility's required minimum of 90% or better, one or a combination of these solutions have the potential of providing other benefits (e.g., increase in lifespan of existing hardware, electricity losses reduced).

<u>Savings Opportunities for Water Pumping Stations:</u>

1. Where time-of-use tariffs and demand charges are used by the utility providing electricity, **investigate options to reduce electrical demand by shifting loads** (from times of higher electrical rates to times of lower electrical rates). One solution could be the addition of water storage capacity, which could be filled during low-cost electrical rate times. Similarly, onsite battery storage could be added for energy arbitrage and resilience. Batteries could be charged with excess solar generation and/or during times of lower-cost electrical rates.

<u>Wastewater Pumping Stations/Wastewater Treatment Plants:</u>

1. **Evaluate changing the design of aeration systems** for wastewater treatment plants. Relocating and replacing blowers to a fixed location outside the aeration ponds. This removes the blowers from the toxic gases and allows for easier maintenance. The blowers would most likely be replaced from multiple smaller ones to a smaller number of lager ones depending on the arrangement. The energy usage will need to be taken into account as other systems are evaluated.

2. **Consider controlling the aeration motors on/off** based on the oxygen content with an oxygen sensors located in the ponds.

Opportunity for Zaragoza Wastewater Treatment Plant

Wastewater treatment plants commonly use an aeration process to help kill bacteria in the water. Currently at Zaragoza Wastewater Treatment Plant the aeration in the aeration lagoon is generated by motors on floating platforms. The treatment process creates hydrogen sulfide (H_2S) as a byproduct. The H_2S creates a corrosive environment that has damaged blowers, motors, and platforms, so that many of Zaragoza's motors have required annual rewinding. The H_2S also poses a health risk to maintenance personnel as they enter the lagoons to service the aerators. Instead, by installing blowers outside of the lagoons and installing aeration piping at the bottom of the lagoons, would provide multiple health and efficiency benefits (i.e., reducing risk of accidents, reducing operations and maintenance cost, and extending the life of the aerators). Relocating the blowers would allow for VFD installation on all the blowers, thus attaining significant efficiency gains. Adoption of this design can result in energy use reduction of 20% or more. This aeration approach could also be evaluated at Las Arenitas as well (as a part of the planned expansion and renovation project).

5.5 Energy Efficiency Opportunities in Durango

The water utility of Durango reports a total of 124 water and wastewater-associated consumption (load) centers, 97 of which are associated with the wells used for provision of drinking (potable) water and 27 of which support wastewater treatment. The combined potable water pumps' electrical usage was nearly three times the amount of energy and costs as the wastewater centers in 2020. Monthly total electricity costs for all facilities from December 2019 thru November 2020 were within 15% of each other. Table 12, below, provides a summary of annual energy use and associated costs for Durango.

Table 12. Durango Annual Energy Use and Costs[26]

TOTAL CONSUMPTION (WATER & WASTEWATER) CENTERS	124
Energy Use (kWh/year)	61,988,698
Energy Cost ($/year) WITHOUT / VAT	**$137,878,331**
DRINKING WATER CONSUMPTION CENTERS	97
Drinking volume capacity (liters per second) (2019) (drinking volume produced) (liters per second) (2019)	4.5 (3.84)
Number of facilities (Nov 19-Oct 20)	97
Energy Use (kWh/year)	**47,779,769**
Energy Cost ($/year) WITHOUT / VAT	$106,093,600
*MXN per kWh for drinking water ($/kWh)	**$2.45**
WASTEWATER CONSUMPTION CENTERS	27
Wastewater treatment capacity (liters per second) (2019)	1,871
Number of facilities (Nov 19-Oct 20)	27
Energy Use (kWh/year)	**13,209,629**
Energy Cost ($/year) WITHOUT / VAT	$31,784,731
MXN per kWh for treated water ($/kWh)	$2.22

Source: Authors with data from Aguas del Municipio de Durango (AMD), (CONAGUA, 2019i)

**In the case of Durango and Torreón, data were not found or not provided, due to the inability to carry out field visits. The concepts were changed to include information that was available for the three operators.*

Aguas del Municipio de Durango (AMD) is the City of Durango's public agency that provides water and wastewater services. AMD is currently evaluating the purchase of energy from a third party. AMD's facilities are affected by blackouts and voltage issues at CFE connections. This damages their equipment and decreases its lifespan due to network distortions.

[26] Calculations completed by report authors, data provided by Mexicali State Public Services Commission (CESPM)

Current Best Practices:

Wastewater treatment plants "Sur" and "Oriente" have robust preventative maintenance schedules for their mechanical and electrical equipment. Similarly, all potable water wells have a preventative maintenance schedule for their mechanical and electrical equipment.

AMD has proactively been examining opportunities to switch to a more optimal (i.e., cost-effective) rate structure or creating additional meters/accounts with CFE at the Oriente WWTP.

Energy Savings Opportunities:

On average, pumps consume 75-90% of total the energy used across all 124 water and wastewater treatment consumption centers. Therefore, energy conservation measures (ECMs) and operational modifications, such as those listed below, associated with pumps may have the most potential for savings.

Savings Opportunities for Water Pumping Stations, Wastewater Pumping Stations, and Wastewater Treatment Facilities:

1. **Compare the cost of adding VFDs to pumps**, versus the expected energy savings for each pump to determine payback.[27]
2. **Explore replacing smaller motors** (less than 2 horsepower (hp) depending availability) with ECM (electronically commutated motor) motors.
3. **Evaluate replacing motors with low power factors** with higher efficiency motors that have higher power factors.
4. **Review control sequences and the staging of pumps** to determine if a more energy efficient configuration is practicable.
5. **Update all interior and exterior lighting to LED**, focusing on sites that have incandescent or older, inefficient fluorescent lighting (e.g., T-12). Also focus on sites with higher-than-average lighting use. For instance, lighting currently uses 7.69% of PTAR-Del Parque total energy usage, which is the highest percent attributed to lighting of any of Durango's wastewater treatment plants.
6. **Consider installing capacitors on transformers' load sides in sites with low power factors (i.e., lower than 90%).** In addition, if there are significant electrical harmonics, then a reactor may be required to stabilize the power. Although the current power factor PTAR-Zaragoza + PBAR-8 and other sites almost meets the utility's required minimum of 90% or better, one or a combination of these solutions have the potential of providing other benefits (e.g., increase in lifespan of existing hardware, electricity losses reduced).

[27] See: https://www.pumpsandsystems.com/how-use-vfds-optimize-water-wastewater-systems

Savings Opportunities for Water Pumping Stations:

1. Investigate options to reduce demand by shifting loads (from times of higher rates to times of lower rates). One solution could be the addition of water storage capacity, which could be filled during low-cost electrical rate times. Similarly, onsite battery storage could be added for energy arbitrage and resilience. Batteries could be charged with excess solar generation and/or during times of lower-cost electrical rates.

Wastewater Pumping Stations/Wastewater Treatment Plants:

1. Evaluate changing the design of aeration systems for wastewater treatment plants. Relocating and replacing blowers to a fixed location outside the aeration ponds. This removes the blowers from the toxic gases and allows for easier maintenance. The blowers would most likely be replaced from multiple smaller ones to a smaller number of lager ones depending on the arrangement. The energy usage will need to be taken into account as other systems are evaluated.
2. Consider controlling the aeration motors on/off based on the oxygen content with an oxygen sensor located in the ponds.
3. Evaluate the usage of bio-gas cogeneration at the wastewater treatment plants.[28]
4. Develop a maintenance schedule for wastewater treatment plant "Del Parque".
5. Meet with CFE representatives to discuss options to divide consumption at the Oriente WWTP into different CFE services to enable consumption outside of peak hours and to discuss potential implications of such actions, such as ceding an above ground line to CFE.

5.6 Energy Efficiency Opportunities in Torreón

The municipal water and sanitation system of Torreón has a total of 94 wells, 48 wastewater pumps, 44 tanks and associated pumps, and 3 WWTP (5 meters) supporting the provision of drinking (potable) water and wastewater treatment. The energy associated with pumping equipment for the drinking water system consumes approximately 87% of the total consumption across all load centers.

[28] https://www.epa.gov/sites/production/files/2015-07/documents/opportunities_for_combined_heat_and_power_at_wastewater_treatment_facilities_market_analysis_and_lessons_from_the_field.pdf
Additionally, other studies like one by the IMTA have identified the Durango Sur plant as potentially being able to use biogas. See https://www.gob.mx/cms/uploads/attachment/file/261712/2017_1303_INFORME_FINAL_IMTA-SENER.pdf

Sistema Municipal de Aguas y Saneamiento de Torreón Coahuila (SIMAS) is the city of Torreón 's public agency that provides water and wastewater services.

Table 13. Torreon Annual Energy Use and Costs[29]

TOTAL CONSUMPTION (WATER & WASTEWATER) CENTERS	142
Energy Use (kWh/year)	114,238,379
Energy Cost ($/year) WITHOUT / VAT	**$208,420,425**
DRINKING WATER CONSUMPTION CENTERS	**94**
Drinking volume capacity (liters per second) (2019) (drinking volume produced) (liters per second) (2019)	851 (407)
Number of facilities (Nov 19-Oct 20)	94
Energy Use (kWh/year)	**90,886,797**
Energy Cost ($/year) WITHOUT / VAT	$174,761,741
MXN per kWh for drinking water ($/kWh)	**$1.92**
WASTEWATER CONSUMPTION CENTERS	**48**
Wastewater treatment capacity (liters per second) (2019)	1,194.06
Number of facilities (Nov 19-Oct 20)	48
Energy Use (kWh/year)	**23,351,582**
Energy Cost ($/year) WITHOUT / VAT	$33,658,684
MXN per kWh for treated water ($/kWh)	$1.44

Source: Authors with data from Sistema Municipal de Aguas y Saneamiento de Torreón Coahuila (SIMAS), (CONAGUA, 2019i)

Current Best Practices:

- **Torreón's staff have proactively renegotiated with the CFE to change the tariff for two large load centers (wastewater pumping stations) to a lower tariff** (for medium voltage agricultural irrigation (RAMT).
- A preventative maintenance schedule is in place for the well pumps.

[29] Calculations completed by report authors, data provided by Mexicali State Public Services Commission (CESPM)

- The pumps at wastewater treatment plant Fundadores appear to have motor starters; implementing this practice at other sites could yield energy savings and enable better control strategies.

Energy Savings Opportunities:

The monthly utility cost data indicate that several meters have no usage (in kWh) but are accruing monthly charges. The utility data for these meters should be investigated to determine if there are indeed no loads on these meters, and if so, the accounts with the utility should be closed. These include the meters listed in Table 14, below.

Table 14. Summary of Electric Meters with no Usage

Tanks	Rate	Meter
Tanque Arista	GDMTO	R670XX
Tanque Reforma	GDMTO	R185YD
Tanque Magdalenas	GDMTO	413DYF

Source: Authors with data from Sistema Municipal de Aguas y Saneamiento (SIMAS) Torreón

Savings Opportunities for Water Pumping Stations, Wastewater Pumping Stations and Wastewater Treatment Facilities:

1. Compare cost of adding VFDs to pumps versus the expected energy savings for each pump to determine payback.
2. Although a preventative maintenance schedule is in place for the pumps, it shows all pumps being serviced in the first three months of the year. Spreading out maintenance and conducting after a certain amount of run hours versus a set timeline may be more effective. Manufacturers of pumps provide guidelines and recommendations for how often a pump should be serviced based on average hours a day of run time. For example, a pump that runs for 24 hours a day will need more maintenance than a pump that runs 4 hours a day. Also, consider replacing pumps that have not been adequately maintained and/or at end of life with more efficient pumps.
3. Review control sequences and the staging of pumps to determine if a more energy efficient configuration is practicable.
4. Investigate options to reduce electrical demand by shifting loads (from times of higher electrical rates to times of lower electrical rates). One solution could be the addition of water storage capacity, which could be filled during low-cost electrical rate times. Similarly, onsite battery storage could be added for energy arbitrage and resilience. Batteries could be charged with excess solar generation and/or during times of lower-cost electrical rates.

5. Update all interior and exterior lighting to LED, focusing on sites that have incandescent or older, inefficient fluorescent lighting (e.g., T-12). Also, focus on sites with higher-than-average lighting use.
6. WWTP Rancho Alegre had a big spike in electrical usage in November 2019 (585,200 kWh), whereas the average usage of the other months was 268,333 kWh. It could be worthwhile to understand, historically, what drove that large surge of load and if that happens annually, investigate options to minimize the large load increase.

5.7 Energy Efficiency Opportunities Conclusions

Numerous energy efficiency opportunities exist in municipal water utilities. They can be categorized into three primary pathways:

1. policies and incentives to promote more efficient use of water by customers;
2. operational or process changes to save energy at treatment facilities; and
3. technical solutions to save energy at treatment facilities.

This section contains a comprehensive listing of potential strategies and measures; some may be applicable to the municipalities while others may not. Nearly all of these measures would result in reductions in energy use, energy expenditures, and greenhouse gas emissions associated with municipal water utilities' energy use.

This project took place during the global COVID-19 pandemic, and therefore the scope and execution of the work was limited by the pandemic. Analysis was not carried out based on data gathered and observations at the municipal water utilities but was rather dependent on data provided by the utilities.

An effective process to identify cost-effective energy efficiency opportunities would be to compare the energy intensity (i.e. energy use per square footage or energy use per treated water) across treatment facilities. Focusing continued efforts on the highest energy consuming (by area or treatment) may yield the most opportunities. A summary of potential energy efficiency measures is included in Table 15, below.

Table 15. Summary of Potential Energy Efficiency Measures

EE Measure	Savings Estimate	Savings Calculator
Adding VDF's to pumps	Up to 20% with no controls upgrade	http://vfds.org/vfd-savings-calculator.html

EE Measure	Savings Estimate	Savings Calculator
Replace smaller motors (less than 2 horsepower (hp) depending availability) with ECM (electronically commutated motor) motors.	Up to 75% percent	
Review control sequences/upgrade controls and the staging of pumps to determine if a more energy efficient configuration is practicable		
Update all interior and exterior lighting to LED, focusing on sites that have incandescent or older, inefficient fluorescent lighting (e.g., T-12). Also focus on sites with higher-than-average lighting use.	Up to 75% (compared to incandescent)	https://www.lightbulbwholesaler.com/t-energy_savings_calculator.aspx
Consider installing capacitors on transformers' load sides in sites wtoith low power factors (i.e., lower than 90%). In addition, if there are significant electrical harmonics, then a reactor may be required to stabilize the power.	Up to 10%	https://www.rapidtables.com/calc/electric/power-factor-calculator.html
Investigate options to reduce electrical demand by shifting loads (from times of higher electrical rates to times of lower electrical rates). One solution could be the addition of water storage capacity, which could be filled during low-cost electrical rate times. Similarly, onsite battery storage could be added for energy arbitrage and resilience. Batteries could be charged with excess solar generation and/or during times of lower-cost electrical rates.	20% - 50% of total energy used at wastewater treatment plant	
Evaluate the usage of bio-gas cogeneration at the wastewater treatment plants	20% - 50% of total energy used at wastewater treatment plant	
Consider aeration process improvements	25% - 40%	
Evaluate replacing motors with low power factors with higher efficiency motors that have higher power.		
Meet with utility representative to discuss options to switch to different utility rate tariff.		

Source: Authors with data from Jenkins (1999), Variable Frequency Drives (2014), National Institutes of Health, Division of Technical Resources (2016), U.S. Department of Energy (n.d.), Lightbulb Wholesaler (2021), Silber (2016), Rapid Tables (n.d.), EPA (2011) & Maktabifard et al (2018).

Key Messages

1. Measures to optimize the demand can have benefits and bring savings. Mainly those that require less investment and that can be implemented in the short term for example, utility bill analysis, implementation of comprehensive operations and maintenance (O&M) protocols or changes in energy demand management in order to have a diagnostic of the initial state of the situation and be able to identify solutions.
2. In water systems the **addition of water storage capacity to the system** (as an energy demand management measure) can help reduce operational costs and provide improved resilience. If storage capacity can be added at an elevation above the distribution network and load centers, **pumping energy can be replaced by gravity fed systems**. This is a measure that will require a large investment so it should be planned carefully and a Cost Benefit Analysis carried out to identify what the long-term savings would be, for example throughout the useful lifetime of the new storage considering possible energy savings to know if it is economically feasible.
3. When there are storage systems in place, savings can be realized by **treating and pumping water at times of reduced electrical rates** (assuming a time of use rate structure is in place) or at times of excess renewable energy production.
4. Pumping related EE solutions have great potential across all three water utilities: drinking water pumps consume at least 75% of total electricity in the facilities.

6. Analysis of Potential Renewable Energy (RE) Opportunities in Municipal Water Utilities

Mexico has always had abundant natural solar and wind RE resources. Only recently, however, has harnessing RE from solar and wind become a viable way for organizations to reduce energy costs while reducing dependence on fossil fuel generated electricity. In the last several years the adoption of RE by organizations has accelerated across Mexico and much of the rest of the world. This has been driven forward by global price declines in RE components and transaction costs, national and state policies, and aspirational commitments by organizations and countries to source 35% of their energy demand from new RE systems by 2024 (and 50% by 2050).[30]

[30] Mexico ratified the Paris Agreement in 2016. Paris Agreement

For many organizations that are used to buying their power from long established regional or national providers, navigating the purchase of electricity from renewable energy sources is not only a relatively new idea, but also likely to fall considerably outside of their area of expertise. To help guide top decision makers and managers on the path to RE, this section of the report will cover two of the main RE electricity procurement approaches utilized in Mexico (purchase the RE system or purchase the power) and look at some of the technical and financial factors that may impact water utilities in the Mexican states of Durango, Mexicali, and Torreón.

In summary, along with energy efficiency improvements, one of the best options for water utilities is an on-site solar energy system that is 500 KW or smaller. On-site solar energy systems can produce environmentally and financially positive returns for pump stations and smaller operations sites (load centers). On-site systems can be purchased outright. Alternatively, instead of buying the system, an organization can purchase the electricity an on-site system produces using a PPA. In the PPA scenario, a third party pays for, owns, operates and maintains the system. The site owner has no out of pocket capital costs and only pays for the electricity the system produces. At a minimum, this approach requires a good site for solar production, suitable roof, ground, or water area for the system installation, and a creditworthy energy purchaser (site owner).

For larger load centers, such as pumping stations, 500 KW on-site systems can provide respectable economic returns, but may not be large enough to cover a significant amount of electricity use. To overcome this and achieve economic savings from RE, organizations can consider combining an on-site solar system with an off-site PPA. In this situation, the organization procures RE via a contract from a solar or wind developer that has or can build a new RE project connected to the regional grid. The electricity purchased counts against the end user's utility bill. Typically, PPAs can provide electricity at a rate equal to or less than utility rates, while providing a hedge against rising rates with contract terms ranging from 10-20 years. Both approaches are discussed in further detail in the following pages.

Another approach for wastewater facilities to consider is bundling or combining multiple load centers demand. By increasing the overall amount of energy demand, facility managers may be able to obtain better pricing for multiple on site RE systems or PPAs that serve their respective sites.

For the purposes of this study, the electricity usage and cost of each for water utility in Durango, Mexicali, and Torreón were modeled to determine how much solar energy would be needed to fulfill 100% of their electricity demand.

Clean Energy Certificates: As opposed to achieving net savings by procuring RE, Mexico's Clean Energy Certificates (CELs) provide a way for utilities and organizations to buy their way out of emission reductions associated with their energy consumption. As of January 2021, CEL policies and market practices in Mexico are being reshaped in the courts -with some cases including constitutional challenges. The associated uncertainty has led to an effective pause in Mexico's CEL market. For organizations that have poor on-site installation conditions or financing ability (credit worthiness), with unforeseen positive changes in policy, CELs may become the least cost approach for achieving corporate or mandated GHG emissions reductions.

For on-site solar, the area needed to install the corresponding system was also calculated (See Table 16). In locations where energy usage is relatively high, facility owners/managers are unlikely to be able to meet all their electricity needs with an on-site solar energy system even with substantial energy efficiency improvements.

As such, off-site PPAs and investment options are also given consideration in this study. In addition, a simple financial model was used (see Appendix 2) to illustrate estimated financial returns of investing by purchasing an RE system (see tables 17 and 18).

In general, under the right conditions, water treatment facilities in Mexico have several potentially viable ways to change their electricity source to lower cost solar and wind generated electricity.

The document has distinguished and divided the sections on EE and RE because the technical and financial elements are distinct and can be taken, and usually are taken, independently. The RE section addresses possibilities at each water utility. This was analysis conducted at a general level because site evaluation and other factors were not possible under this specific phase of work.

Barriers

Several of the main barriers to procuring renewable energy in Mexico include:

1. Water utility owners and operators do not have experience and knowledge of potentially viable renewable energy procurement options.
2. The roof and land area within a specific water utility may not have sufficient space for RE systems to support a significant portion of their electricity demand.
3. Competing sources of energy for producing electricity may be relatively cheap, subsidized, or impacted by market prices that do not accurately reflect the full social and environmental costs of a particular source of energy. For example, if the actual costs of producing electricity with fuel oil are subsidized and no other sources of energy receive a similar subsidy, fuel oil will have an advantage and other sources will have a higher financial hurdle to clear so as to be competitive in that market.
4. Policy changes and uncertainty make it difficult for RE providers to plan and operate their businesses. Any changes to the electricity market operation rules will directly affect power generators, resulting in stranded investments. Fast changing regulation also makes it challenging for potential RE buyers to understand and evaluate the long-term benefits.

Feasibility analysis & tools

Feasibility studies for RE are site-specific and typically include one or more visits to the site for evaluation. This is done because sites have different roofs, lands area, tariffs, electrical systems, proximity to interconnection locations, and financial goals and capabilities - to name several of the variables.

A water utility manager could learn to evaluate the feasibility of RE for their site, but without a professional assessment of the site, expert system design skills, market knowledge about components, labor, and other costs, a full feasibility assessment will be challenging.

The more traditional path is to secure technical and costs proposals through an RFP process or by working directly with private sector experts that provide EPC services. Most solar and wind providers that are reputable will provide free site evaluations that include technical and financial proposals, so once an offer is made and secured, the water utilities will benefit from this on-site free evaluation. For a skilled utility manager, online tools that can be used to assist in evaluating the feasibility of a site include:

Wind and Solar Assessment tool:

https://www.nrel.gov/gis/renewable-energy-potential.html

PV Watts for estimating solar production:

https://pvwatts.nrel.gov/

Levelized costs of electricity:

https://www.nrel.gov/analysis/tech-lcoe.html

6.1 Purchasing Solar and Wind Energy

There are two main paths for water treatment facilities in Mexico to pursue their financial and environmental goals through the procurement of renewable energy:

1. Purchase an on-site RE system, and
2. Purchase the power a system generates via a PPA

6.1.1 Purchase an on-site RE system

RE generating systems that are purchased by an organization are almost always located on-site at the facility. On-site systems are usually solar panels based with

DC to AC inverters connected to the facility's electrical system (usually behind meter). Common installation locations include roof, ground, or, more expensive, car park (shading structures) and floating (solar arrays). Floating solar panels systems can be used on storage ponds, reservoirs, and retention ponds, for example. The costs of floating solar panels systems are reported to be 5-10% higher than ground mounted arrays (Haugwitz, 2020)[31]. The design, engineering, and installation of RE systems can be paid for with cash from capital accounts or with partial debt financing (e.g. commercial bank loans and public bond issuances). Additionally, the purchase of on-site solar energy systems requires ongoing O&M costs, precluded by legal and accounting costs associated with contract negotiations and execution.

For uninitiated organizational decision makers, purchasing a system may seem to be a daunting prospect from a facility management or financial perspective. However, depending on a facilities situation,[32] a typical on-site solar energy system can provide net economic gains in 3-7 years, with compounding financial returns in the form of energy costs savings thereafter (20-30 years). By purchasing a system, an organization accrues all the economic benefits. By purchasing the power that a RE system generates through a PPA, the benefits are the same, but the economic returns are split with the system owner/investor.

6.1.2 Purchase the power a system generates via a PPA

Organizations that choose not to purchase a solar energy system but would like to use renewable energy to power their facilities can use a PPA to procure RE from a Qualified Supplier. PPAs are commonly utilized for buying electricity from on-site solar energy systems. For locations that have large loads but an insufficient area available for an on-site solar installation a substantial portion of their electricity needs may be covered with a PPA[33] for RE from an off-site wind or solar plant.

Regardless of the location of the RE system, with a PPA, the buyer of the electricity from the system gets an equivalent (kWh) reduction in their utility bill, while an outside investor(s) pays for the system and installation, owns the system, and is responsible for ongoing O&M. Investors make returns when they sell electricity to the buyer.

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[31] See: https://www.pv-magazine.com/2020/09/22/floating-solar-pv-gains-global-momentum/

[32] For example: the sites solar access and shading characteristics, electricity demand curve and costs, as well as dynamic market and policy conditions.

[33] These are sometimes commonly referred to as 'virtual' PPAs because the RE based electricity is not provided directly to the site, but the purchaser can receives an equivalent reduction in the usage/generation component of their electricity bill and claim credit for emissions reductions via Certificates of Clean Energy (CELs) or similarly bundled environmental attributes, even if they are not required to do so by law. In Mexico, users can register as Voluntary Entities and offset Clean Energy Certificates. http://diariooficial.segob.gob.mx/nota_detalle_popup.php?codigo=5431464

For organizations buying power, PPAs have become an attractive way to negate capital expenditures limitations while achieving economic savings and environmental objectives.

- To qualify for a PPA an organization has to have a good credit rating and
- will need to hire an experienced lawyer to negotiate the PPA terms on their behalf.

The basic general terms of a PPA that are negotiated by the buyer and seller include:

- Price of the electricity: which can be flat or a discount against the utility tariff, the other one reduces price volatility and the second one only secures a discount.
- Price index or annual escalator or consumer price index.
- The length of the agreement: usually 10 to 20 years for on-site PPA whereas for off-site PPA, in Mexico, a 3-year PPA is possible. The longer the period the greater the saving.
- The guaranteed amount of energy that will be supplied and purchased for the term of the agreement, and compensation rates if production falls short.

There are several types of PPAs:

1. Direct PPA -These typically apply to systems that are located on-site, but the RE system is owned by a third party. Off-site RE systems can enter into direct PPAs with site owners, but it is less common than using a virtual PPA or contract for differences approach.

2. Virtual PPA (VPPA) - These are also known as financial PPAs, in that they are contracts for the purchase of energy between two parties. When the electrons of RE generated cannot be directed to the buyer's site, a VPPA can be still be used to purchase the power from the generations facility. Here, the production of the RE and its sale are made at a distribution node where energy markets operate. In policy environments where the price of the energy cannot be set (fixed) between two parties and is subject to market flucuations, power purchase agreements are often structured as a Contract of Differences, in which an agreed upon price for energy is specified in a contract with the knowledge that that price will be different from the spot market price over time. If the contract price is greater than the market price, the generator pays the difference to the buyer (off-taker). If the market price is more than the contract prices, the seller keeps the difference. These agreements can have floors and ceiling, put and call options, and a variety of other financial considerations.

Further information can be found here:

https://www.bancomext.com/wp-content/uploads/2018/12/Modelos_de_negocio_ER_Bancomext_GIZ.pdf

https://s3.amazonaws.com/cdn.orrick.com/files/Renewable-Energy-PPA-Guidebook-for-CI-Purchasers-Final.pdf

https://my.solarroadmap.com/userfiles/PPA-Customers-Guide.pdf

https://en.wikipedia.org/wiki/Power_purchase_agreement

IRENA: Power Purchase Agreement for Variable Renewable Energy

https://www.irena.org/-/media/Files/IRENA/Agency/Events/2018/Aug/Renewable-Energy-PPAs.pdf?la=en&hash=C365D5D08EBFF26A1F7A29A13D721C5B3C4390D9

NREL: Power Purchase Agreement Checklist for State and Local Governments

https://www.nrel.gov/docs/fy10osti/46668.pdf

RE Financial modeling tools can be found on NREL's website:

https://sam.nrel.gov/financial-models

In nearly all cases, the cost of the electricity procured through a PPA can be 10-30% lower than current utility rates, depending of energy volume, correlation between consumption and generation, dispersions/concentration of center loads and end user credit worthiness.

6.2 RE for Water Utilities in Mexico

To provide a better understanding of how water treatment organizations in Mexico can evaluate the viability of RE for their facilities, the study presented in this section of the report looks at electricity use, costs, and renewable energy potential across 172 associated facilities (metered load centers owned by water treatment organizations) located in the Mexican cities of Durango, Mexicali, and Torreón.

To assist in providing some comparative contrast, the 10 largest load centers in Mexicali and Torreon, and 86 mid-range loads centers in Torreon are discussed in the following pages.[34] Data provided by Durango was for 4 pumping stations and the Durango staff requested to focus on these large loads.

The Mexicali and Torreón cases encompass a broad perspective on the energy challenges facing water treatment organizations serving 700,000 to a 1 million people. The total MWh of electricity used across 114 of Mexicali's billed meters is

[34] Mexicali staff indicated that they would like to see a focus on the 10 sites with the largest electricity use. Torreon staff indicated that larger loads had recently shifted to a lower tariff and requested a focus on the mid-non-sump pump load centers.

just over 48,000 MWh a year. For the mid-range loads in Torreon, the total MWh used in 2020 amounted to: 88,300 MWh.[35] For Durango, the data provided, and thus the analysis presented here is limited to four of the main treatment plants, which used 17,654 MWh in 2019.

Table 16. Total Electricity Use & Average Cost

	MWh/Yr	MXN$/kWh	USD $/kWh*	# of Meters
Durango	17,654	1.91	0.095	4
Mexicali	48,087	2.07	0.104	114
Torreón	107,072	2.12	0.106	154
Mexicali: Top 10	36,650	1.59	0.080	10
Torreón: Top 10	26,974	1.75	0.087	10
Torreón: Mid-range	88,286	1.94	0.097	85

Source: authors with data from Comisión Estatal de Servicios Públicos de Mexicali (CESPM), Aguas del Municipio de Durango (AMD), Sistema Municipal de Aguas y Saneamiento de Torreón Coahuila (SIMAS)

Notes: ** Exchange rate of 20 pesos per $1 USD*

Where electrical usage and/or costs data was inconsistent, missing, or loads were very small, sites (meters) were excluded from this analysis. Source: Data provided by Municipalities of Durango, Mexicali, and Torreon

As Table 15 shows, electricity prices vary across the locations. This can be explained by two main factors:

1. Relative cost of electricity on the regional grid (in the node); and
2. The size of the load center.

Meters at smaller load centers tend to pay higher cost per kWh, as compared to larger load centers such as pumping stations -regardless of location.

For example, in Mexicali, the cost of electricity on averages is 2.07 $MXN/kWh (0.104 USD/kWh) across all (114) of the sites, as can be seen in Table 15. When the focus is narrowed to the 'Top 10' largest electricity load centers in Mexicali, the cost of electricity is about 20% lower at: 1.59 $MXN/kWh and 1.75 $MXN/kWh without VAT, for the Top 10 in Torreón[36].

[35] Locations with incomplete or no usage data and those that used less than 150 kWh of electricity use per month were not included in this study, see Research Design section can be found in Appendix 2.

[36] Torreon staff reported that in addition to 1.3 MXN$/kWh for their two biggest sites, prices for the other large load centers was (or has been) renegotiated at a lower tariff, this would seem to mean the 1.75 average is too high, but it is what the data from 2020 showed.

In contrast, the cost for mid-range loads centers in Torreon are 1.94 $MXN/kWh. Marginal electricity costs for the four pumpings stations in Durango were found to be highest on average at a price point of 1.9 MXN$/kWh ($0.095 c USD/kWh)[37]. This may reflect the higher costs of electricity on the Durango's regional grid.

Generally, the three cities have about the same solar energy potential: ~1,945 peak solar sun hours per year (kWh). Table 17 shows the average system sizes and amount of space (area) needed for system installation.

For organizations that are considering on-site solar to help power their facilities, detailed electricity **usage load profiles and installation location specific production analyses are critical pieces of information that have to be determined** through a professional on-site evaluation.[38]

For this project, on site visits were not possible to conduct because of the COVID-19 sanitary emergency. Hence, all the presented data and calculations are assumptions and were collected from different sources. Where sites are known to be heavily impacted by shading and other factors that decrease solar potential, such as the site "Del Parque" in Durango, organizations can look to off-site solar energy procurement which is discussed in the following pages.

Finally, where load centers are on a Time-of-Use electricity rate schedule, shifting consumption to off peak hours by changing load timing and battery storage can be viable strategies for reducing costs.

For mid-range to small load centers, that can be covered by a 500 kW solar energy system or smaller, if there is enough available on-site area that is unshaded and facing south, an organization may be able to meet their electricity needs with on-site RE after energy efficiency improvements. (As a point of reference, a 500 KW system would require about 6,000 square meters.) However, smaller RE systems can cost more on a per unit ($/KW) basis to install that system over 1 megawatt, see NREL: https://www.nrel.gov/analysis/tech-lcoe-re-cost-est.html, for more information on cost on installation by size.

To overcome this, organizations can combine load centers in a request for proposals for multiple on-site system installations. **By aggregating projects, bidders can provide lower costs as economies of scale are reached** with more purchasing power and standardized transaction documents across sites -this would be a good strategy for Torreon mid-range locations.

[37] This analysis assumes the data provided for Durango included VAT pricing, while data for Mexicali explicitly excludes VAT. Durango appears to have higher average electricity prices, which cannot be explained by the lower cost for higher loads ascertain.
[38] Load profiles should be for kWh usage during 15 minute or hourly intervals over the course of a year -if available. Most solar companies will provide site evaluations for free as part of a financial proposal for engineering, procurement and installation.

Table 17. Solar Potential and Installation Area[39]

	Annual Sun Hours	Average kWh/Month	Solar System Size (KW)**	Area for Installation (m^2)
Durango	1,950	280,871	1,728	20,741
Mexicali*	1,938	9,476	59	704
Torreón*	1,944	46,677	288	3,458
Mexicali: Top 10	1,938	305,415	1,891	22,693
Torreón: Top 10	1,944	224,784	1,388	16,651
Torreón: Mid-range	1,944	86,555	534	6,411

Source: Authors with data from (CESPM), (AMD), (SIMAS).

*Notes: *Includes all sites except the top 10 load centers, **Solar system sizes are estimated averages for a typical site.*

Annual sunhours by site estimates used in this table (section) are: Durango (1,950 horas), Mexicali (1,938 horas) y Torreón (1,944 horas).

System sizes are estimated using the demand at each water facility divided by the production potential of a typical PV system in each municipality. Estimated system sizes are general average, e.g. 1 KW of PV requires 100-200 sq ft (9.29 a 18.58 m^2).

As can be seen in Table 17, larger load centers (Top 10), on average will require between 1-2 hectares of solar to neutralize their electricity consumption from the grid. While these locations are likely to fare well with a 500 kW on-site system, some **may** not have adequate space even with energy efficiency improvements. In such cases, aggregating loads in an RFP for off-site electricity procurement via a PPA may prove to be a worthwhile strategy. This approach is discussed further in the next section.

It is worth considering that for Torreon the total would be 0.59 unshaded square kilometers (km2), Mexicali would be about half of that (0.27 km2), and for the four pumping stations in Durango, about 10-25 Ha would be need to off-set 100% of electricity usage with solar.

[39] Figures for this table were based on: Solar insolation rates are based on data from https://power.larc.nasa.gov/data-access-viewer/

6.3 Energy costs and RE return on investment

In Mexico's most recent auction for the supply of energy, record low bids for solar and wind power generated electricity were submitted by dozens of solar and wind companies. The average bid (price) was less than 1 pesos per kWh (6.68 pesos per MWh, $.0335 cents USD/kWh) (Bloomberg New Energy Efficiency [BNEF], 2016)[40]. That is nearly 70% less than what wastewater treatment facility <u>retail rates</u> observed in this study. Water utilities should not expect to see such low price offers for RE[41].

<u>Reducing Costs with RE (purchasing the power)</u>

Purchasing electricity is an overhead cost for running an organization. The funds spent on electricity have no possibility of providing a positive return on investment. Positive returns can only be achieved by investing in (factors of production) sources of electricity with lower marginal cost over time.

Organizations that do not want to directly purchase a solar energy system, but would like to use renewable energy to power their facilities can, in most cases, use a RE PPA to reduce their electricity costs. Table 18 shows estimated saving that may be possible.

The savings figures are determined by taking the total amount of energy (MWh) used by each of three groups and multiplying by electricity rates and estimated PPA market prices to determine the total cost of electricity over 15 years.

The results show the estimated savings over 15 years when switching to a RE PPA -in the column on the far-right side of the table Gei emissions savings are show. While this analysis cannot provide definitive cost, savings estimates for each and every facility, it generally illustrates the potential of utilizing an PPA to procure electricity from RE.

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[40] BNEF, 2018. "Mexico's second power auction results: Record low prices in Latin America" https://data.bloomberglp.com/bnef/sites/14/2017/01/BNEF_MexicosSecondPower_SFCT_FNL_B.pdf
And: www.greentechmedia.com/articles/read/mexico-auction-bids-lowest-solar-wind-price-on-the-planet

[41] First, recent auction bid prices are only for the generation component of a retail electricity price, additional costs paid by the end user include transmission, distribution, taxes, and other administrative costs. These factors can add 30%-50% more costs to the final retail price paid at the meter. Second factor that helps explain the low bids offered in auctions is related to the size (economies of scale) of the RE projects proposed -sizes ranged from a 30 MW minimum to 505 MW. In contrast, to cover the average site (load center) in Durango, Mexicali's Top 10 or Torreón's Top 10, would require about 1-2 MW of RE. Other factors for a low auction price: volume of energy, length of the contract (15 years), off-taker (CFE Suministrador Básico) credit risk and the competition ambient created around it.

Table 18. Estimated Savings due to PPA Renewable Energy Purchasing and Potentially Avoided Emissions

	Total energy (MWh/ yr)	Utility Rates (MXN$/ MWh)	Utility Cost (15 yrs.)	PPA Cost (15 yrs)	Estimated Saving Renewable Energy PPA (MXN)	Estimated tCO2e savings in GHG
Durango	17,654	1,910	-505,726,992	-404,581,593	101,145,398	8,721.076
Mexicali: Top 10	36,650	1,590	-874,125,823	-743,006,950	131,118,873	18,105.1
Torreón: Top 10	26,974	1,750	-707,907,575	-601,721,439	106,186,136	13,325.156

Source: Authors with data from (CESPM), (AMD), (SIMAS).

Estimates assume no annual increase in Utility or PPA rates. Cash Flows are not discounted. Figures are for discussion purposes only and do not constitute a guarantee of costs or savings. Emission factor for Mexico in 2020: 0.494 tCO2e/MWh

Because deal terms between the buying and selling parties for PPAs in Mexico are private and not typically made publicly available, savings over utility rates cannot be precisely enumerated here. However, limited PPA pricing data and common sense makes it clear, RE procured via a PPA can often be provided at or below current utility rates. For example, in Mexico several notable companies have entered into private bi-lateral PPA for solar power - Bayer (100 MW), Heineken (28.8 GWh), Zodiac Aerospace Equipo de Mexico (200 MW). Moreover, based on bids made by RE developers for private bilateral PPA offers in Mexico that CEIA participated in, prospective RE PPA buyers with good installation sites or large demand (for off-site) can expect to see prices that are 10%-30% below the retail cost of electricity.

Investment returns with RE (purchasing the system)

If an organization invests directly into a new RE plant (on or off-site) they have the potential to turn an overhead cost into a positive net economic return. Table 19 shows the potential impact of hypothetical scenarios in which prespecified loads are replaced with RE generating plants that are owned by the organization.

For investors, on-site projects in Mexico are usually optimized at 500 KW or smaller, due in large part to Mexico's net-metering/billing policy which caps eligible projects at 500 KW. Sites with smaller loads tend to have installation conditions that are less than optimal, e.g. roof faces to the east and west but not the south or partial shading in the installation area. On a per KW basis, smaller systems also cost more to install than systems over a 1 MW due to terms that RE installers can get for by ordering parts and components in ‘bulk’. However, because small load centers also tend to have higher utility rates (2-2.8 MXN$/kWh) than can still achieve positive economic returns with investments in on-site RE.

Table 19 shows the estimated average turnkey installation costs for 100 kW and 500 kW with Internal Rates of Return (IRR)[42] of 10-11% and positive Net Present Value (NPV)[43] over the course of 20 years, using a 10% discount factor.

Higher discounts rates will reduce the estimated returns, lower discounts will have the opposite effect. Regardless, while the analysis suggests that NPV will be positive with moderate returns in most situations, financial analysis is highly site/situationally specific and those offered here are for illustrative purposes only.

Table 19. Combining Demand and Investing in RE

Load Centers	MW	Capex (MXN$)	IRR	NPV (MXN$)
Smallest	0.100	$2,000,000	11.0%	$124,220
Small	0.5	$9,000,000	10.2%	$93,660
Medium	5	$80,000,000	11.8%	$8,833,440
Multiple	30	$420,000,000	13.3%	$85,979,340

Source: Authors based on confidential information, (Feldman et al, 2020), (Feldman & Margolis, 2020) and (GIZ,2020)

For facilities with relatively larger loads, organizations can expect to pay less per KW for installations of RE systems, compared to systems under 500 kW or smaller, on a per unit (MXN/KW) basis. However, systems over 1 MW and up, tend to have lower cost per installed KW. Where RE systems are ground mounted, floating, or off-site the amount of electricity (kWh), they can be designed and installed to produce the maximum solar potential (kWh per KW installed). On average, these systems will be more efficient than a typical rooftop RE system with fixed set of installation characteristics (e.g. azimuth, inclination, and shading). The impacts of these factors overwhelm the impact of lower electricity prices. As summarized in Table 19, larger systems are likely to result in the best overall economic performance.[44]

The savings figures and investment returns presented in this analysis are estimated based on favorable generalizations and assumptions about site conditions, organizational credit worthiness, dynamic policy variables, and other variables. To obtain accurate pricing, potential savings, and investment return figures, organizations will have to seek bids for the purchase RE that is specific to their situation and employ professional financial support to evaluate the economic implications for their organization.

[42] See: https://www.investopedia.com/terms/i/irr.asp
[43] See: https://www.investopedia.com/terms/n/npv.asp

[44] See Appendix 2 for details on modeling assumptions used for the Tables included in this section.

An in-depth description of the research design used for these calculations can be found in Appendix 2.

6.4 Conclusion: Procuring RE for Water Treatment Facilities

Water treatment facilities that are considering RE to power their facilities in Mexico have several, potentially viable ways to switch electricity sources, save money, and reduce GHG emissions.

For facilities with relatively small peak load (~500 kW, peak) on-site solar is likely to provide the best opportunity for cost savings. On-site systems can be purchased outright, or the electricity that a (third-party owned) on-site system produces may also be purchased via a PPA. For either approach, organizations should have a professional technical and financial evaluation of the site to account for specific solar insolation rates, economic conditions, roof, ground, water, electrical, safety, and other key considerations. Usually this can be accomplished by contacting a 3-4 solar provider directly or through a Request for Proposals process that allows pre-qualified solar contractors that offer purchase and PPA options to compete for your business.

For organizations that are seeking to maximize savings across their facilities, the strategy of combining load centers (e.g. water treatment pumping stations and administration and maintenance buildings) can increase purchasing power, create economies of scale, and reduce transaction costs, resulting in more competitive pricing across sites vs. individual sites on a piecemeal basis.

Organization that would like to explore financing the purchase of a renewable energy system (or investing in an off-site projects) an increasing number development and commercial and development banks in Mexico may provide support, e.g. Inter-American Development Bank, North American Development Bank (NADBank[45]), and Mexican development banks e.g. Bancomext, and, private banks, MUFG Bank, BBVA Bancomer (Thurston, 2018)[46].

It is recommended that the selection of a suitable financing source be carried out once the business model and the specific financing need have been defined. For this it is important to take into consideration:

1. If the water utility falls within the jurisdiction of the financial institution, for example the NADBank.

2. If a loan is required or non-refundable support is sought or a mixture of both?

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[45] NADBank is binational Bank that only operates 100 km above or below the border between Mexico and USA providing technical assistance, grant or loans both private or public sector.

[46] See: https://cleantechnica.com/2018/12/24/multilateral-banks-pile-onto-mexico-solar/

3. What type of banking is being considered: commercial, development or other like FONADIN?

4. Who will invest in the project, a Public entity (Banobras), Private or both, the water utility and the banks or funds?

5. What services will be hired?

6. What will be the payment guarantees of the water utility?

Key Messages

1. For facilities with relatively larger loads, organizations can expect to pay less per KW for installations of RE systems, compared to systems under 500 kW or smaller, on a per unit (MXN/KW) basis. However, systems over 1 MW and up, tend to have lower cost per installed KW.
2. Positive returns for energy projects can only be achieved by investing in (factors of production) sources of electricity with lower marginal cost over time.
3. Organizations that do not want to directly purchase a solar energy system, but would like to use renewable energy to power their facilities can, in most cases, use a RE PPA to reduce their electricity costs.
4. In nearly all cases, the cost of the electricity procured through a PPA can be 10-30% lower than current utility rates, depending of energy volume, correlation between consumption and generation, dispersions/concentration of center loads and end user credit worthiness.

7. Financial Strategy: EE+RE

7.1 Overcoming barriers to before starting EE/ER projects

Information

The data availability in the water sector and at a local level is not completely systematized or is hard to access. Although PIGOO is in place, it is not mandatory for water utilities to report the requested data, and this often results in outdated information. Federal actors have good visualization tools and aggregated data that provides a good overview of the sector as a whole. However, detailed information from local actors is vital for conducting energy efficiency and renewable generation projects, in order to guarantee their success, impact, and that the benefits are reaped by local communities (or in this case, the water utility operators). As observed information across water utilities varies greatly, making it difficult to systematically compare it, and to assess and make the correct decisions with the biggest impact.

- It is advisable to systematize the water and energy consumption information in each meter and consumption center over several years, identified why information is missing and events that are out of the ordinary to overcome the lack of data.
- Well-organized information will support the planning process to attract financing, so it is advisable to establish an internal procedure to improve data generation, registration and reporting. An improvement in this regard will also help to report performance and issues about climate change mitigation efforts.
- It is to consider whether this improvement in data generation, registration and reporting process can be proposed as a project to federal institutions and agencies within the framework of both operational improvements and MRV systems to improve transparency in operations.

Legal conditions

New energy tariffs are not seen as an opportunity by water utilities so most of them have not identified the potential to reduce their energy bills in a sustainable way. The capacity (kW) charge represents an interesting opportunity due to solar PV being recognized as capacity, and the potential for more efficient equipment replacement as an EE measure. The challenge is to find legal conditions that secure third party investment (public or private) via medium-long term contracts (PPA) either for on-site or off-site (qualified supplier).

- Technical and legal pathways should be identified for following:

  (i.) how legal and technically consumption centers could be grouped?

  (ii.) how to establish alliances with other regional water utilities to combine volume in such a way that it is easier to attract investments?

  (iii.) legal issues to consider about make contracts with qualified suppliers?

  (iv.) legal issues to establish a better combined credit rating that requires capacity building?

- The actors involved in the decision-making process with influence on investment decision must be identified and considered, as well as the period of the administration in which a project planning should be executed.
- These barriers should be overcome before starting the process of attracting financing.

Cost Benefit Analysis (CBA) and capacity building

Public decentralized water utilities have expertise in operations, energy management and monitoring, but usually lack of deep understanding on the energy legal framework and lack of contracting experience in the energy sector could be a risk.

It is important to develop capacities regarding the aforementioned experience gaps in the legal and technical framework of the energy sector and for the development of CBA's in order to carry out the evaluation of the different measures proposed in this study.

- One way to build these capacities is to identified personal with this experience within the water utility and integrate them into the working group for these issues. The CBA and the energy sector legal framework and PPA contracting requires at beginning external consultants in order to transfer knowhow about CBA, contracts and energy market rules to the water utility. The understanding of this will improve chances to get support from federal programs and to attract investment from third parties.

7.2 Potential Savings Summary

Table 20 below shows the potential savings (in energy or money) that a water utility could achieve if it applies EE or RE solutions in its facilities.

Table 20. Energy conservation measures and potential savings

Energy Conservation Measure (ECM)	Purchase equipment		Third party service (no capex): Power Purchase Agreement & Energy Service Agreement	
	Energy Saving (%)	Individual equipment cost	Estimated Savings	Capital Cost
Adding VDF's to pumps	Up to 20% with no controls upgrade	<5 kUSD	-	-
Replace smaller motors[47] <2HP	Up to 75% percent	> 5 kUSD <25 k USD	-	-
Replace all incandescent bulbs with LEDshigher-than-average lighting use.	Up to 75% (compared to incandescent)	1 LED = ~USD$3.00	-	-
Installing capacitors on transformers' load sides in sites with low power factors (i.e., lower than 90%).	Up to 10%	> 70 USD <5 k USD	-	-
Evaluate replacing motors with low power factors with higher efficiency motors that have higher power.	Depends on current energy patterns and equipment	> 150 USD <2 k USD	-	-
RE Smallest Load Centers (0.1 MW)	Depends on the ratios between consumed and self-generated energy	$2,000,000 MXN	5%-10%	None to low cost
RE Small Load Centers (0.5 MW)	Depends on the ratios between consumed and self-generated energy	$9,000,000 MXN	5%-10%	None to low cost
RE Medium Load Centers (5 MW)	Depends on the ratios between consumed and self-generated energy	$80,000,000 MXN	8% - 12%	None to low cost

[47] Replace smaller motors (less than 2 horsepower (hp) depending on availability) with ECM (electronically commutated motor) motors.

Energy Conservation Measure (ECM)	Purchase equipment		Third party service (no capex): Power Purchase Agreement & Energy Service Agreement	
	Energy Saving (%)	Individual equipment cost	Estimated Savings	Capital Cost
RE Multiple Load Centers (30 MW)	Depends on the ratios between consumed and self-generated energy	$420,000,000 MXN	8% - 15%	None to low cost

Source: *Authors*

Note: VFD: Variable frequency drive

7.3 Business models for PV in Mexico

There are currently three ways to procure solar energy in Mexico. Purchasing a PV system, signing a contract for leasing a PV system, or registering as a Qualified User and signing a PPA with a Qualified Supplier for off-site energy. Table 21 below shows the main characteristics of each option and the type of user who would benefit from it. An on-site solution could be paired with an offsite PPA for covering the remaining electricity that is not generated by the PV system.

Table 21. PV business models: key features

	Key features	Relevant customers
Option 1: On-site turnkey purchase	· Often lowest cost of electricity per kWh over system's lifetime; · Reduces electricity costs; · Requires investment up-front from the customer to purchase the system; · Customer is responsible (carrying cost and risk) for the PV system operations and maintenance; · Tax benefits available.	Relevant for users that have: · Sufficient sunny rooftop or ground space; and access to capital to purchase a system. Most cost-effective for customers with: · Peak demand under 500 kW; · Owned facilities planned to be in operation for 10 years or more; · Facilities operating seven days per week; and · Energy demand that aligns with likely hours of RE generation.
Option 2: On-site third party PPA or lease	· Reduces electricity costs; · Offers instant savings on utility bills as there are no up-front	Relevant for users that have: · Sufficient sunny rooftop or ground space;

	Key features	Relevant customers
	costs and uses operational, not capital, budget; • The third-party system owner is responsible (carrying cost and risk) for ensuring the PV system operates well and produces the maximum possible electricity	• Limited access to capital for an outright system purchase or that focus on other investments that are key to business operations; and • The ability to sign long-term contracts (10–20 years). Most cost-effective for customers with: • Peak demand under 500 kW; • Businesses operating seven days per week; and • Energy demand that aligns with likely hours of RE generation.
Option 3: Off-site third party PPA (Qualified Supplier)	• Reduces electricity costs • Offer instant savings on utility bills as there are no up-front costs and it uses operational, not capital, budget; • Allow customers to buy RE from sources beyond solar (e.g., wind); • Offer lower generation costs via economies of scale (but customers still must pay for transportation/market operation fees); and • Provide savings on a much larger percentage of customers' electricity bills.	Relevant for users that have: • Flexibility to contract with qualified suppliers as qualified users; • Limited capital for an outright system purchase; • A site that may not be conducive to RE; • Leased facilities or that are planning to move their operations in the next few years; and • The ability to sign long-term contracts (10–20 years). Most cost-effective for qualified users with: • Demand greater than 500 kW. • Facilities NOT operating seven days per week, or. • energy demand that does NOT align with on-site generation.

Source: Authors

7.4 Next steps for attracting financing

When selecting a financial scheme for procuring clean energy and launching an RFP (see Appendix 3) water utilities should take into consideration the following characteristics of the systems or equipment. Water utilities should include which type of offers they are looking for depending on whether they wish to own the system and equipment (turnkey purchase) or would rather sign a long term contract with a third-party (PPA or lease). Table 22 below compares both models from a financial perspective. Strong investment capacity is needed for turnkey projects, and willingness to sign contracts for more than 10 years is needed for a PPA or lease, as well as payment guarantees like cash or stand-by credit letters.

Table 22. PV financial models

Characteristics	Turnkey purchase	Third party financing (PPA or lease)
Ownership	Customer PV developer or other outside investors (i.e. third party)	PV developer or other outside investors (i.e. third party)
Up-front capital investment	On customer's balance sheet (cash or loan/line of credit)	PV developer or other outside investors (i.e. third party)
Project financing	On customer's balance sheet (cash or loan/line of credit). Construction and project financing capital is sometimes bundled.	Financing from PV developer or other investors (i.e. third party)
Operations and maintenance	Customer's responsibility. Usually a separate contract with a PV developer or a third-party O&M provider is secured.	Cost included in PPA/lease.
Equipment warranties	Recommended for inclusion as part of the initial system procurement. May not cover the full life of all equipment (e.g. inverters) over project life.	Third party owner manages the warranties and is responsible for PV system's operational risk beyond warranties.
Performance guarantees (minimum kWh production level or customer does not pay)	Production performance guarantees can be negotiated with project developers but are rare with a turnkey purchase. PV panel manufacturers typically provide production guarantees for 20-25 years on their panels.	Widely offered and included with PPAs, performance guarantees must be in contract language that includes annual minimum kWh guarantees and compensation rates in case of shortfalls.
Insurance	Customer's responsibility. May be included under existing insurance policy or require a separate policy.	Third-party owner is responsible for PV system's operational risk. Liability and property insurance responsibility should be clarified.
Lowest cost per kWh over PV system lifetime	Yes	No
Potential cash-flow positive in first year	No	Yes

Source: Authors

Key Messages

1. As a first step, water utilities should examine which low investment measures are feasible to be implemented, estimate the personnel and time required for their planning and implementation. For this, it is advisable to establish indicators for the measures to follow up as indicated in Appendix 3.
2. The choice of what type of energy supply and the selection of the business model must be based on a good CBA.
3. It is required to deepen through a detailed analysis in the field the economic viability of each one of them.

8. Conclusions

8.1 Considerations for Water Utilities when planning energy related projects

New energy tariffs represent a challenge for water operators, since there is no tariff specific for water pumping like before. Still, water utilities can take advantage of the new electricity tariff model by reducing consumption in peak hours or installing solar panels to stop paying for electricity during the day. The capacity (kW) charge represents an interesting opportunity due to solar PV being recognized as capacity, and the potential for more efficient equipment replacement as an EE measure.

An effective process to identify cost-effective energy efficiency opportunities in a facility, to assess GHG emissions impacts, could be to compare the energy intensity (i.e., energy use per square footage or energy use per unit treated water). Focusing continued efforts on the highest energy consuming (by area or treatment) may yield the most opportunities for water utilities, both for EE and RE solutions.

The new tariff scheme may have resulted in exponential rising costs of electricity, but it also represents an opportunity for energy management. This strong market signal is more effective than environmental regulations to seek operational changes and reduction in energy consumption.

8.2 A Growing Need for New Business Models

One of the challenges identified for water utilities is the setting of rates for the payment of the public service. The problem lies in the fact that the final decision to set the rate scheme does not rest with the water utility, and that the calculation methodology is different in each of the state water laws, which can generate controversy.

However, the water utility can propose rates that allow its economic self-sufficiency through specific studies that allow it to properly substantiate the proposal presented to the corresponding institution. To learn more about methodologies for setting a water rate, consult the Book "Tariff Structures" # 54 of the CONAGUA Drinking Water, Sewerage and Sanitation Manual (CONAGUA, 2019e).

- Tariff prices directly impact the bankability of the energy projects.

On the other hand, the recovery of costs for the service provided and the identification of funds to manage investments in hydraulic infrastructure are actions of great relevance for the financial stability of the water utilities.

Federal resources for the water and wastewater sectors have steadily declined. Currently, only a third of the budget that was in 2016 is in place, making it complex to invest in grants for upfront projects like EE and RE projects.

- New business models with no or little investment (such as a PPA) could be implemented and could bring benefits if some conditions are in place. Water utilities need to keep up-to-date accountant books to prove their financial strength, as well as proof of equipment maintenance, a baseline for their energy consumption and more information that is detailed in the Appendix 3 roadmap.

Public decentralized water utilities have expertise in energy management and monitoring, but usually lack funding, have superficial energy framework understanding and do not necessarily have contracting experience in the energy sector, or the faculties for investing in a PV system, or signing long term contracts. However, there are loans for both equipment and for PV systems that utilities can take advantage of, like the ones mentioned in Section 3.5.

New investment or financial strategies

Public resources can also be used in a different way in order to increase impact and scalability.

- CONAGUA can implement warranties covering credit risk associated with mid-long-term contracts between the public and private sector. Instead of grants. This can be applied to both PPAs and to EE projects

- CONAGUA can implement revolving credit lines. Funding programs tend to use population scale and rural/urban indicators to prioritize resources allocation and classify water utilities that way.
- New funds could be built specifically for EE and RE projects. To participate in such new funds, WU should comply with some conditions, for example:
  - water coverage percentage is high.
  - a determined efficiency in micro-monitoring is in place
  - efficiency in billing is already achieved

This is because energy improvements should be made only if the water utility is running a solid operation, and the community's needs are being covered, regardless of its size.

- FONADIN could modify its operating guidelines as well as those of PROMAGUA's to open a specific line for EE and RE projects, under the condition of a two-stage financing scheme similar to the one the Green Climate Fund currently has. It should be subjected, for example, to a Technical Need Assessment that clarifies in detail the costs and benefits of each measure. In other words, include a CBA.
- To improve the bankability of projects, a general tariff scheme should be proposed that considers maintenance needs, equipment replacement planning and the requirements for increasing resilience to climate change.
- Water operators should be legally allowed to establish investment groups or companies to increase their credit rating and for economies of scale. Projects of 2 or 3 water operators from the same state would be more easily bankable.

By following the steps included in the roadmap in Appendix 3, water utilities can assess their current energy consumption, their goals and needs, and design an energy strategy that best fits them. Financing considerations should be included from the beginning, in order to decide which procurement option (Table 21) and which model (Table 22) aligns with the vision of the utility and reaps the most benefits.

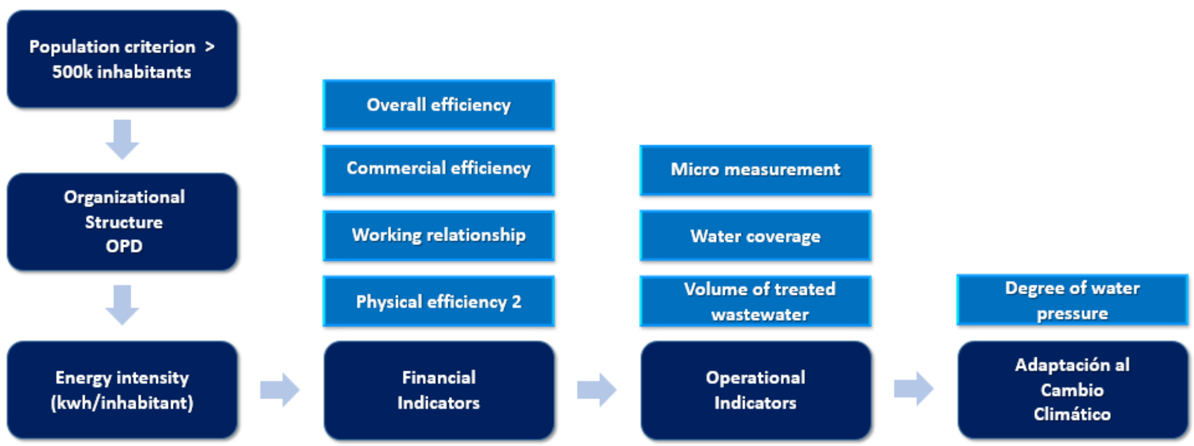
Appendix 1. Methodology

Selection Process

Indicators, Data Collected and Sources

In order to complete this study's objective and provide in-depth support to three municipalities, it was necessary to define key criteria to evaluate: the GHG emissions mitigation potential (in terms of energy intensity); operation and finances of the water utilities (technical, financial and operational efficiency), as well as the probability of implementation and replicability for the EE and RE projects. The selected indicators, their respective sources, and the corresponding analysis are presented below.

Figure 5. Selection Criteria



Source: Authors

Population with more than 500 thousand inhabitants

INEGI's 2015 intercensal survey identifies that there are 74 metropolitan areas in Mexico (CONAPO, 2015b). In 2017, the National Population Council (Consejo Nacional de Población [CONAPO]) projected that 62.75% of the population (77.50 million inhabitants) was concentrated in these areas. "37 metropolitan areas have more than 500 thousand inhabitants, which represents a total of 67.10 million people and 54.32% of the national population" (CONAGUA, 2018a). Forty-two municipalities and their respective water utilities meet this preliminary population criterion.

Organizational Structure

This indicator seeks to increase the probability of both implementation and scaling and is directly related to financial issues. Recalling that water utilities can have four types of organizational structure: Centralized (attached to the municipality), Decentralized, Concessioned or a Rural committee (INEGI, 2016), each structure has its limitations and advantages.

Ideally, a decentralized water utility should have a model similar to that of formal, centralized, for-profit organizations[48] (emphasizing that economic benefits are invested in the body itself), in which the owner or proprietor is not a person, but a governing board, represented internally by the administrator or director (CONAGUA, 2019f).

This study specifically deals with public decentralized water utilities because they have important characteristics such as having their own legal standing, in addition to having their own patrimony and autonomy in the decision-making process (CONAGUA, 2019f). This is in contrast to centralized public agencies, which do not have any of these characteristics. Finally, Concessioned water utilities were discarded from this study because there are very few water utilities with this structure and, thus, replicability would be limited[49].

Of the forty-two (42) municipalities analyzed, the following were found: 27 decentralized public agencies (2 of them are intermunicipal agencies[50]), 18 concessions[51] (10 municipalities have concessions for the entire water service and in 8 the private company only operates 1 or 2 main wastewater treatment plants) 1 organization attached to the municipal government (Sistemas de Agua y Saneamiento de Centro), and 1 mixed paramunicipal company (Aguas de Saltillo) See Table 26.

Renewable Energy Solutions

Within the municipalities that meet the previous indicators (more than 500 thousand inhabitants and public decentralized water utilities), some water utilities have been identified that have experience with clean energy projects. Most of them, as shown in Table 5, have opted for cogeneration projects, while others have installed solar panels, and one has signed a PPA.

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[48] Similar to small businesses, whose main objective is to make a profit. To do this, they have a formal organizational structure (even if it is basic) and authority tends to focus on the owner or owners (governing board), who have the last word (SGAPDS 2019).

[49] Some selected water utilities have a concession to a private hydraulic infrastructure (e.g. WWTP), however, they have passed our selection criteria because they have remaining infrastructure that can utilize EE and RE solutions.

[50] SIAPA (Intermunicipal System of Potable Water and Sewerage Services) provides the service to the municipalities of Guadalajara, Tlaquepaque and Zapopan and SADM (Water and Drainage Services of Monterrey, I.P.D) to the municipalities of Apodaca, Guadalupe and Monterrey.

[51] Only 13 private companies were found, as some provide the service to more than one municipality (Agua de México, Atlatec, FYPASA Construcciones and Proactiva Medio Ambiente).

The Electricity Industry Law makes a distinction between renewable energy (solar and wind, being the most common) and clean energy (nuclear, hydroelectric and cogeneration, among others) (H. Congress of the Union, 2014). This study seeks to incentivize and amplify clean energy sources that do not emit emissions of any kind during their operation. Therefore, our methodology discarded the water utilities that operate a wastewater treatment plant with cogeneration technologies or other clean energy solutions under their jurisdiction.

Operating Energy Intensity and Emissions per Inhabitant

The indicator focuses on the public decentralized water utilities with the highest potential for reducing GHG emissions, something that is closely related to the amount of energy consumed to provide services to users given that water and wastewater services are public.

For this indicator, data on energy consumption at the city level was extracted with the CFE pumping rate for water or wastewater (or T6), from CRE, (2017); this data was then divided between the total number of inhabitants of the municipality, using data from the INEGI Population Census (2010). For the estimation of this indicator the following equation was applied.

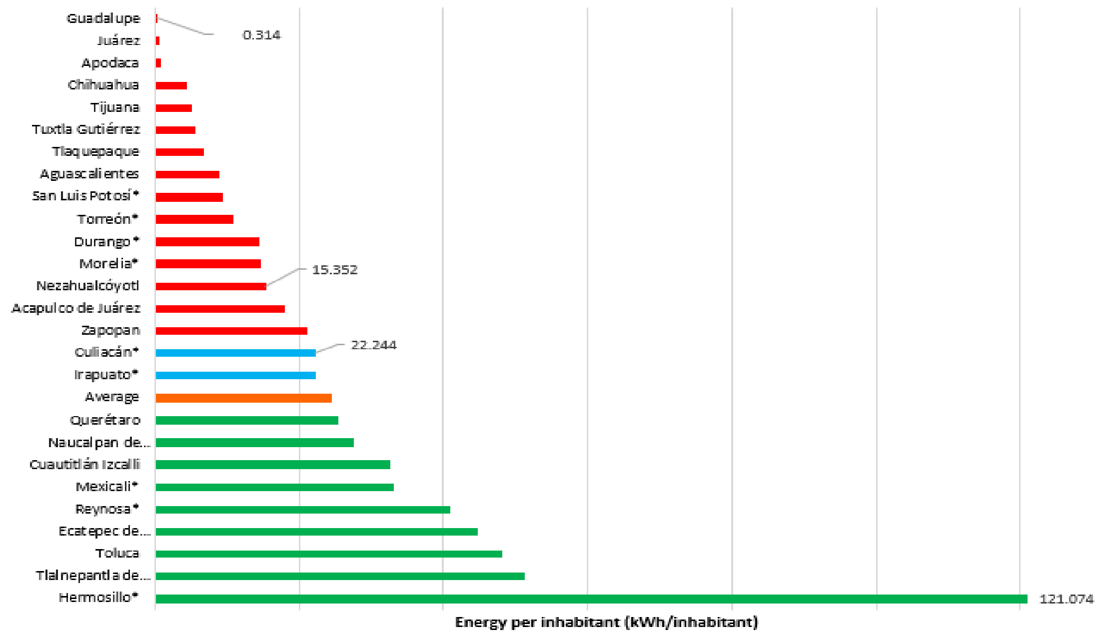
$$Ind\ Epc = \frac{Anual\ comsumption\ (T6), 2017 (KWh)}{Habitants\ in\ 2017} *\ EF_{2017}$$

$Ind\ Epc$	Operating Energy Intensity and Emissions per Inhabitant (tCO_2e/hab.)
EF_{2017}	Emissions Factor of the year 2017 = 0.582 tCO_2/MWh[52]

The data for this indicator has been selected as it is the most recent publicly-available data that can give indication of the energy consumption and energy efficiency of the public decentralized water utilities and their respective need to adopt energy efficiency and renewable energy solutions. The average energy intensity is 24 kwh/inhabitant and, as shown in Figure 6, Hermosillo is the municipality with the highest electricity demand per inhabitant. To provide an idea of the potential for mitigating emissions, Figure 7 is presented with the estimate of emissions released by the energy consumed in water services per inhabitant. The average emission released per inhabitant of the municipalities analyzed is 12.38 kg CO2e/MWh*Inhab.

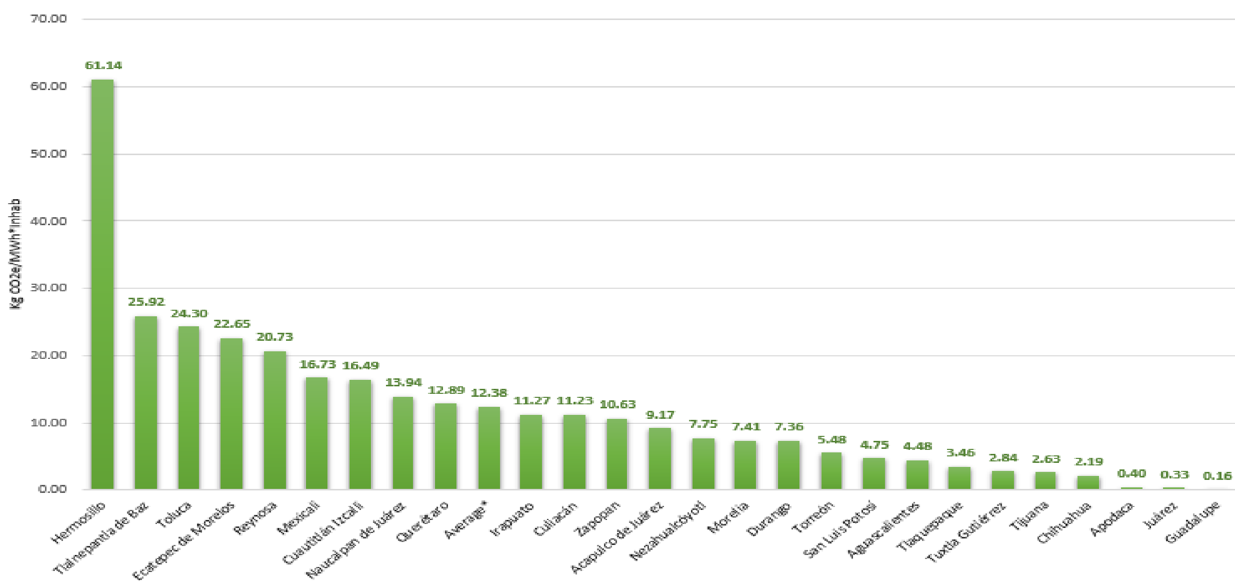
[52] See: https://www.gob.mx/cms/uploads/attachment/file/304573/Factor_de_Emisi_n_del_Sector_El_ctrico_Nacional_1.pdf

Figure 6. Energy consumption per Inhabitant (KWh /Inhab)



Source: *Authors with data from CRE (2017) and INEGI (2011)*

Figure 7. Emissions released per inhabitant for the energy consumption to provide water services (Kg CO_2e/MWh*Inhab)



Source: *Authors with data from CRE (2017), INEGI (2011) and Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT] (2021)*

Note: *The CRE emission factor is 0.505 tonCO2e / MWh*

Table 23 below shows the data used to build the previous two figures.

EPC: Specific Capacity per habitant EC: Specific Consumption per habitant
EE: Specific Emissions per habitant

Table 23. Data for emissions and energy consumption

	EPC (KW/Hab)	CE (MW/Hab)	EE (ton CO2e/ MWh * Hab)	EE (Kg CO2e /MWh * Hab)
Hermosillo*	121.07	0.12	0.06	61.14
Tlalnepantla de Baz*	51.33	0.05	0.03	25.92
Toluca	48.11	0.05	0.02	24.3
Ecatepec de Morelos	44.86	0.04	0.02	22.65
Reynosa*	41.05	0.04	0.02	20.73
Mexicali*	33.14	0.03	0.02	16.73
Cuautitlán Izcalli	32.66	0.03	0.02	16.49
Naucalpan de Juárez	27.6	0.028	0.014	13.94
Querétaro	25.52	0.026	0.013	12.89
Promedio	24.51	0.025	0.012	12.38
Irapuato*	22.31	0.022	0.011	11.27
Culiacán*	22.24	0.022	0.011	11.23
Zapopan	21.05	0.021	0.011	10.63
Acapulco de Juárez	18.15	0.018	0.009	9.17
Nezahualcóyotl	15.35	0.015	0.008	7.75
Morelia*	14.67	0.015	0.007	7.41
Durango*	14.57	0.015	0.007	7.36
Torreón*	10.86	0.011	0.005	5.48
San Luis Potosí*	9.41	0.0094	0.0048	4.75
Aguascalientes	8.88	0.0089	0.0045	4.48
Tlaquepaque	6.85	0.0068	0.0035	3.46
Tuxtla Gutiérrez	5.63	0.0056	0.0028	2.84
Tijuana	5.209	0.00521	0.00263	2.63
Chihuahua	4.331	0.00433	0.00219	2.19
Apodaca	0.784	0.00078	0.00040	0.40
Juárez	0.65	0.00065	0.00033	0.33
Guadalupe	0.314	0.00031	0.00016	0.16

Source: Authors with data from INEGI and CRE

Management Indicators Program for Water Utilities

Since 2005, the Mexican Institute of Water Technology (Instituto Mexicano de Tecnología del Agua, IMTA) has evaluated the performance of water utilities. This work is called the Program of Management Indicators of Water Utilities or "PIGOO" (Programa de Indicadores de Gestión de Organismos Operadores) [53].

This performance assessment is carried out using a set of indicators (29 indicators) and, throughout the history of this program, a total of 387 water utilities have been evaluated. In 2019, 146 water utilities were evaluated that, in total, help provide a third of the country's users with services. The PIGOO indicators reflect the operational aspects of the water and wastewater sector, along with the related financial issues and efficiencies (Hansen, M. & Rodríguez, J., 2019).

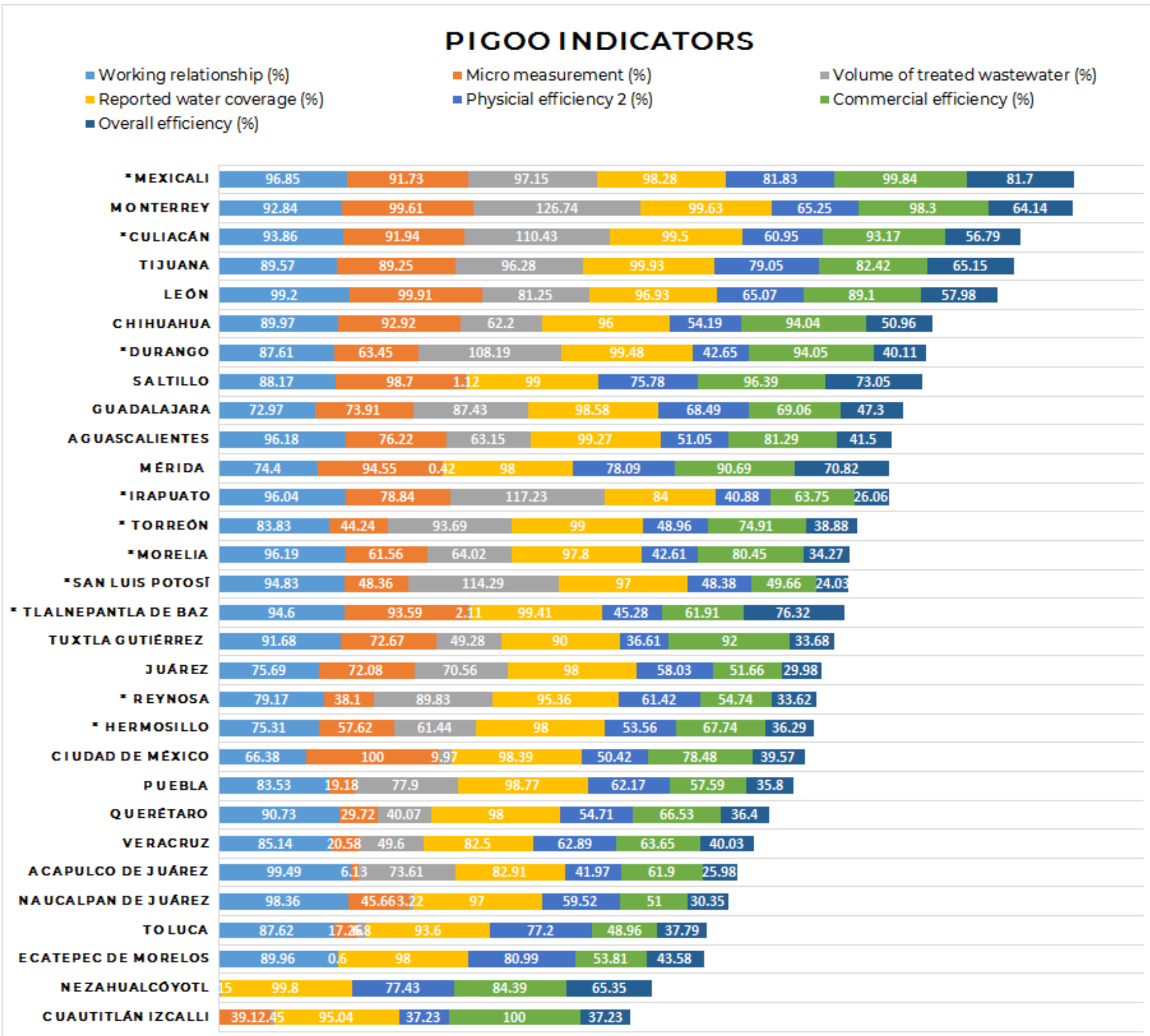
The data collected came from the most recent publicly available data from the decentralized water utilities. At the time of the analysis and selection process, we highlighted the decentralized water utilities with the most up-to-date data (at least until 2015). The indicators selected for the analysis evaluate economic well-being and operational efficiency of the preselected water utilities:

- Working relationship (%): Evaluates the financial reliability of the water utility and its flexibility to incorporate GHG emissions mitigation projects (the average is 88.22%).
- Micro-measurement (%): This indicator assesses the water utilities' control of water and the rationalization of the resource.
- Volume of Wastewater Treated (%): This indicator evaluates the treatment coverage of the wastewater produced. The higher the percentage of treated water, the greater the energy required for its treatment, which increases the mitigation potential.
- Reported Water Coverage (%): This indicator evaluates the percentage of the population that has drinking water services, as well as the size of the distribution and consumption network that is able to reach households. The higher the percentage of drinking water distributed, the greater the energy required for its treatment and distribution, thus increasing the GHG emissions mitigation potential.
- Physical Efficiency 2 (%): This indicator evaluates the efficiency between billed and produced water. It reflects the control of billing and the accounting capacity of the water produced and delivered.
- Commercial Efficiency (%): Assesses the efficiency between billing and collection. It reflects the efficiency of the utility to collect the payments billed for water consumption and, therefore, their respective cash flows.
- Overall Efficiency (%): This indicator calculates the overall efficiency of the drinking water system. It reflects the water utility's efficiency in recovering expenses corresponding to the volume of water produced and provides an idea of financial solvency.

[53] See: http://www.pigoo.gob.mx/

The following Figure shows how each of the 30 water utilities scored on the PIGOO indicators, and we can see that the Mexicali utility (CESPM) is at the top of the list of operators analyzed.

Figure 8. Summary of PIGOO Indicators



Source: Authors based on data from the Program of Management Indicators of Operating Organizations - PIGGO (IMTA, 2018)

The following table 24 shows the PIGOO data for the Figure 9.

CPV: Cost of produced volume **WR:** Work Relationship **MM:** Micro-measurement **TWV:** Treated Water Volume
DWC: Drinking Water Coverage **FE2:** Physical Efficiency 2 **CE:** Commercial Efficiency **GE:** Global Efficiency

Table 24. Data from PIGOO

Year	Municipality, State	Water Utility	CPV ($/m3)	WR (%)	MM (%)	TWV (%)	DWC: (%)	FE2: (%)	CE (%)	GE (%)
2013	Acapulco de Juárez, Guerrero	CAPAMA (Comisión de Agua Potable y Alcantarillado del Municipio de Acapulco)	-	99.49	6.13	73.61	82.91	41.97	61.9	25.98
2018	Aguascalientes, Ags.	CCAPAMA (Comisión Ciudadana de Agua Potable y Alcantarillado del Municipio de Aguascalientes)	8.73	96.18	76.22	63.15	99.27	51.05	81.29	41.5
No reporta	Álvaro Obregón, CDMX	AMSA (Agua de México S.A. de C.V.)								
No reporta	Apodaca, Nuevo León	SADM (Servicios de Agua y Drenaje de Monterrey, I.P.D)								
No reporta	Benito Juárez, Q. Roo	CAPA (Comsión de A.P.A. del Estado de Quintana Roo)								
No reporta	Centro, Tabasco	SAS (Sistema de Agua y Saneamiento)								
2018	Chihuahua, Chih.	JMAS (Junta Municipal de Agua y Saneamiento de Chihuahua)	7.08	89.97	92.92	62.2	96	54.19	94.04	50.96
No reporta	Chimalhuacán, EDOMEX	ODAPAS (Organismo Descentralizado de APA y SMTO. De Chimalhuacán)								
2017	Ciudad de México, CDMX	SACMEX (Sistema de la Ciudad de México)	13.31	66.38	100	9.97	98.39	50.42	78.48	39.57
No reporta	Coyoacán, CDMX	Industrias del Agua de la Ciudad de México, S.A. de C.V.								
No reporta	Cuauhtémoc, CDMX	Proactiva Medio Ambiente SAPSA S.A. de C.V.								

Year	Municipality, State	Water Utility	CPV ($/m3)	WR (%)	MM (%)	TWV (%)	DWC: (%)	FE2: (%)	CE (%)	GE (%)
2017	Cuautitlán Izcalli, EDOMEX	OPERAGUA (Organismo Operador de Agua de Cuautitlán Izcalli)	7.1		39.1	2.45	95.04	37.23	100	37.23
2018	Culiacán, Sinaloa	JAPAC (Junta de Agua Potable y Alcantarillado de Culiacán)	11.6	93.86	91.94	110.43	99.5	60.95	93.17	56.79
2016	Durango, Dgo.	AMD (Aguas del Municipio de Durango)	4.4	87.61	63.45	108.19	99.48	42.65	94.05	40.11
2011	Ecatepec de Morelos, EDOMEX	SAPASE (OPD para la prestación de servicios de Agua Potable, Alcantarillado y Saneamiento de Ecatepec)	10.52	89.96	0.6		98	80.99	53.81	43.58
2018	Guadalajara, Jalisco	SIAPA (Sistema Intermunicipal de los Servicios de Agua Potable y Alcantarillado)	7.66	72.97	73.91	87.43	98.58	68.49	69.06	47.3
No reporta	Guadalupe, Nuevo León	SADM (Servicios de Agua y Drenaje de Monterrey)								
No reporta	Gustavo A. Madero, CDMX	Proactiva Medio Ambiente SAPSA S.A. de C.V.								
2017	Hermosillo, Sonora	AGUAH (Agua de Hermosillo)	10.32	75.31	57.62	61.44	98	53.56	67.74	36.29
2018	Irapuato, Guanajuato	JAPAMI (Junta de Agua Potable, Drenaje, Alcantarillado y Saneamiento del municipio de Irapuato)	7.37	96.04	78.84	117.23	84	40.88	63.75	26.06
No reporta	Iztapalapa, CDMX	Tecnología y Servicios de Agua S.A. de C.V.								
2018	Juárez, Chihuahua	JMAS (Junta Municipal de Agua y Saneamiento de Juárez)	8.02	75.69	72.08	70.56	98	58.03	51.66	29.98
2018	León, Guanajuato	SAPAL (Sistema de Agua Potable y Alcantarillado de León)	19.56	99.2	99.91	81.25	96.93	65.07	89.1	57.98
2012	Mérida, Yucatán	JAPAY (Junta de Agua Potable y Alcantarillado de Yucatán)	3.85	74.4	94.55	0.42	98	78.09	90.69	70.82

Year	Municipality, State	Water Utility	CPV ($/m3)	WR (%)	MM (%)	TWV (%)	DWC: (%)	FE2: (%)	CE (%)	GE (%)
2018	Mexicali, Baja California	CESPM (Comisión Estatal de Servicios Públicos de Mexicali)	12.61	96.85	91.73	97.15	98.28	81.83	99.84	81.7
2018	Monterrey, Nuevo León	SADM (Servicios de Agua y Drenaje de Monterrey, I.P.D)	17.92	92.84	99.61	126.74	99.63	65.25	98.3	64.14
2016	Morelia, Michoacán de Ocampo	OOAPAS (Organismo Operador de Agua Potable, Alcantarillado y Saneamiento de Morelia)	9	96.19	61.56	64.02	97.8	42.61	80.45	34.27
2017	Naucalpan de Juárez, Estado de México	OAPAS (Organismo de Agua Potable, Alcantarillado y Saneamiento de Naucalpan)	20.27	98.36	45.66	3.22	97	59.52	51	30.35
2013	Nezahualcóyotl, México	ODAPAS (Organismo Descentralizado de Agua Potable, Alcantarillado, y Saneamiento de Nezahualcóyotl)	10.55			1.15	99.8	77.43	84.39	65.35
2018	Puebla, Puebla de Zaragoza	SOAPAP (Sistema Operador de Agua Potable y Alcantarillado de Puebla)	11.22	83.53	19.18	77.9	98.77	62.17	57.59	35.8
2018	Querétaro, Querétaro	CEA (Comisión Estatal de Aguas de Querétaro)	11.06	90.73	29.72	40.07	98	54.71	66.53	36.4
2016	Reynosa, Tamaulipas	COMAPA (Comisión Municipal de Agua Potable y Alcantarillado de Reynosa)	6.43	79.17	38.1	89.83	95.36	61.42	54.74	33.62
2018	Saltillo, Coahuila de Zaragoza	AGSAL (Aguas de Saltillo)	2.55	88.17	98.7	1.12	99	75.78	96.39	73.05
2015	San Luis Potosí, San Luis Potosí	INTERAPAS (Organismo Intermunicipal de Agua Potable, Alcantarillado y Saneamiento de San Luis Potosí)	5.73	94.83	48.36	114.29	97	48.38	49.66	24.03
2018	Tijuana, Baja California	CESPT (Comisión Estatal de Servicios Públicos de Tijuana)	10.31	89.57	89.25	96.28	99.93	79.05	82.42	65.15
2018	Tlalnepantla de Baz, Estado de México	OPDM (OPD para la prestación de servicios de Agua Potable, Alcantarillado y Saneamiento del Municipio de Tlalnepantla)	13.72	94.6	93.59	2.11	99.41	45.28	168.55	76.32

Year	Municipality, State	Water Utility	CPV ($/m3)	WR (%)	MM (%)	TWV (%)	DWC: (%)	FE2: (%)	CE (%)	GE (%)
No reporta	Tlalpan, CDMX	AMSA (Agua de México S.A. de C.V.)								
No reporta	Tlaquepaque, Jalisco	SIAPA (Sistema Intermunicipal de los Servicios de Agua Potable y Alcantarillado)								
2016	Toluca, Estado de México	AYST (Organismo de Agua y Saneamiento de Toluca)	13.63	87.62	17.26	6.8	93.6	77.2	48.96	37.79
2015	Torreón, Coahuila de Zaragoza	SIMAS (Sistema Municipal de Aguas y Saneamiento de Torreón)	9.09	83.83	44.24	93.69	99	48.96	74.91	38.88
2016	Tuxtla Gutiérrez, Chiapas	SMAPA (Sistema Municipal de Agua Potable y Alcantarillado de Tuxtla)	7.41	91.68	72.67	49.28	90	36.61	92	33.68
2017	Veracruz, Veracruz de Ignacio de la Llave	SAS (Sistema de Agua y Saneamiento de Veracruz)	4.81	85.14	20.58	49.6	82.5	62.89	63.65	40.03
No reporta	Zapopan, Jalisco	SIAPA (Sistema Intermunicipal de los Servicios de Agua Potable y Alcantarillado de la ZMP de Guadalajara)	13.31							

Source: Authors from PIGOO data

Degree of Pressure on Water Resources (Vulnerability to Climate Change)

To analyze the vulnerability of the population and therefore of the decentralized water utilities' vulnerability to climate change, the indicator representing the degree of pressure on water resources was selected. The higher the degree of pressure, the greater the efforts for water utilities to extract, distribute, treat and dispose of these resources. The percentage that represents the water used for consumptive purposes[54] with regards to renewable water [55] is an indicator of the degree of pressure exerted on the water resource of a country, basin or region. The degree of stress can be very high, high, medium, low and unstressed. If the percentage is between 40 and 100%, a high degree of pressure is exerted, and when it is greater than 100% very high (CONAGUA, 2018a).

The data collected is at the state, hydrological-administrative region and hydrological sub-basin level. This data was extracted from the National Water Information System of CONAGUA and from the Water Risk Atlas AQUEDUCT.

Table 25. Water stress data

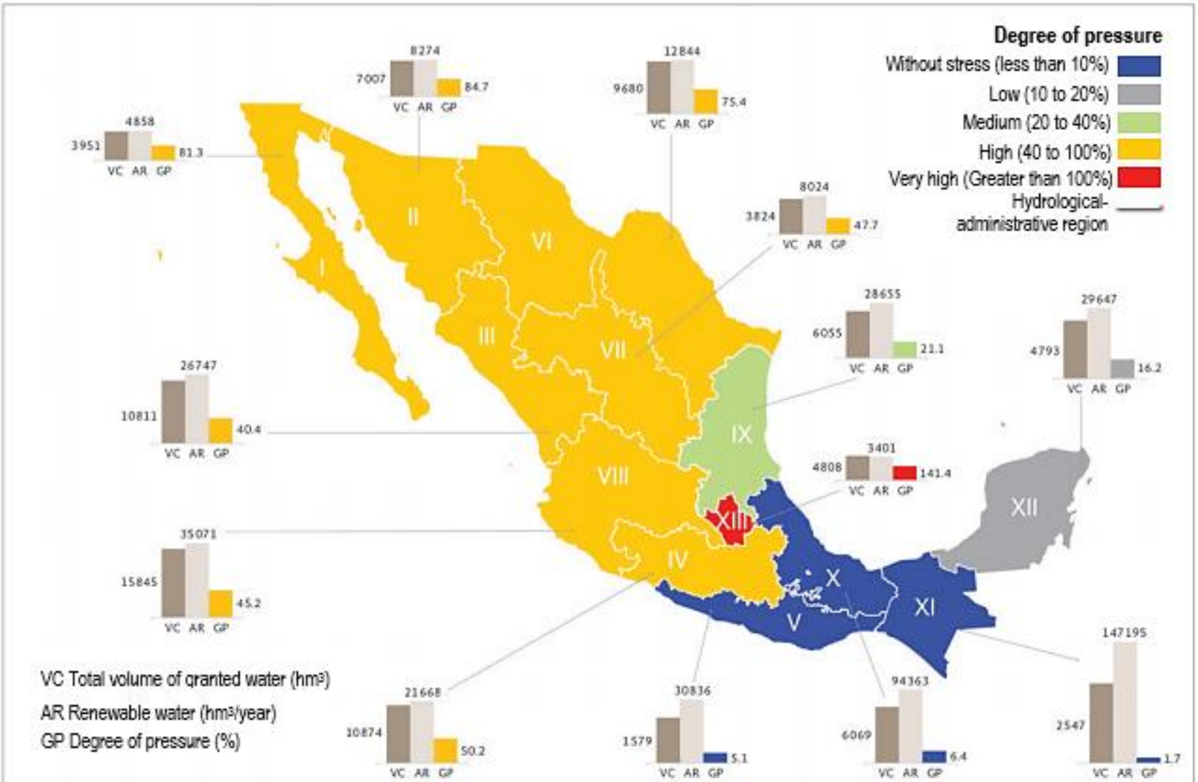
Municipality	Water Depletion (Aqueduct WRI, 2019)	State Level Water Stress (CONAGUA, 2018) (%)	
Mexicali	High (50-75%)	114.4	Very High
Culiacán	Low-Medium (5-25%)	109.07	Very High
Morelia	High (50-75%)	43.25	High
Tlalnepantla de Baz	Medio-Alto (25-50%)	63.26	High
Hermosillo	Alto (50-75%)	102.90	Very High
Durango	Bajo-Medio (5-25%)	11.87	Low
Irapuato	Alto (50-75%)	105.23	Very High
San Luis Potosí	Bajo-Medio (5-25%)	19.12	Low
Reynosa	Bajo-Medio (5-25%)	47.49	High
Torreón	Bajo-Medio (5-25%)	63.8	High

Source: Authors from CONAGUA

[54] Consumptive use: volume of water of a certain quality that is consumed when carrying out a specific activity, which is determined as the difference in the volume that is extracted, less the volume that is discharged. (Ley de Aguas Nacionales, 1992, Art. 3).

[55] Renewable water: Maximum amount of water that is feasible to exploit annually in a region, that is, the amount of water that is renewed by rain and water from other regions or countries (imports). It is calculated as the mean annual internal surface natural runoff, plus the total annual recharge of aquifers, plus inflows minus outflows of water to other regions (Gleick,2002 cited by CONAGUA, 2018a).

Figure 9. Degree of Pressure on the Water Resource, 2017



Source: *Adapted from Statistics on Water in Mexico, (CONAGUA, 2018a)*

Selection Methodology Results

A final filter with the Operating Energy Intensity and PIGOO indicators was made. Special considerations were made in this filter:

- "Operating Energy Intensity" and the service coverage indicators "volume of wastewater treated" and "reported water coverage" were highly considered. Therefore if a water utility had desirable values (greater than or very close to the calculated average) it passed the filter.
- If the water utility had a desirable operating energy intensity but several indicators under the group average it was discarded.
- The water utilities that had less desirable values of operational energy intensity (with the lower limit of 9 kWh / inhabitant) but highly desirable values in the two service coverage indicators passed the filter.

Table 25 shows the average values of the water utilities that were desirable for our initial selection criteria. Overall, if the water utility had high number values across most categories, it also had better monitoring systems and control of its finances and cash flows.

Table 26. Average Values of The Indicators

Working Relationship	88.22
Micro-measurement	62.67
Volume of Wastewater Treated	60.74
Reported Water Coverage	96.24
Physical Efficiency 2	58.76
Commercial Efficiency	75.05
Overall Efficiency	45.82
Operating Energy Intensity	23.33 kWh/inhab

Source: Authors

Pop.: Population (INEGI, 2011) **WU:** Water Utility **OE:** Organizational Structure **CE/RE:** Clean/Renewable Energy
EC: Energy Consumption (kWh) (Tariff 6) (CRE, 2017) **OEIH:** Operating Energy Intensity (kwh/inhab)
OPD: Decentralized Public Utility **Conc.:** Concesion **AMG:** Attached to the Municipal Government

Table 27. Indicator data for the selection methodology

Municipality	State	Pop.	WU	OE	CE/RE	EC (kWh)	OEIH (kwh/inhab)
Acapulco de Juárez	Guerrero	789,971	CAPAMA	ODP	-	14,339,581	18.152
Aguascalientes	Aguascalientes	797,010	CCAPAMA	OPD	-	7,047,413	8.876
Álvaro Obregón	CDMX	727,034	AMSA	Conc.	-	-	-
Apodaca	Nuevo León	523,370	SADM	OPD	-	410,464	0.784
Benito Juárez	Quintana Roo	661	Aguakán	Conc.	-	-	-
Centro	Tabasco	640,359	SAS	AMG	-	-	-
Chihuahua	Chihuahua	819,543	JMAS	OPD	-	3,549,639	4.331
Chimalhuacán (1)	México	614,453	ODAPAS	OPD	-	-	-
Coyoacán	CDMX	620,416	Industrias del Agua de la Ciudad de México	Conc.	-	-	-
Cuauhtémoc	CDMX	531,831	Proactiva Medio Ambiente SAPSA	Conc.	-	-	-
Cuautitlán Izcalli	México	511,675	OASCUATLANIZCA LLI	ODP	-	16,711,351	32.66
Culiacán	Sinaloa	858,638	JAPAC	ODP	-	19,099,5443	22.244
Durango	Durango	582,267	AMD	ODP	-	8,484,237	14.571
Ecatepec de Morelos	México	1,656,107	ODP SAPASE	ODP	-	74,287,623	44.857
Guadalajara	Jalisco	1,459,189	SIAPA	ODP	Yes	-	-
Guadalupe	Nuevo León	678,006	SADM	ODP	-	213,133	0.314
Gustavo A. Madero	CDMX	1,185,772	Proactiva Medio	Conc.	-	-	-

Municipality	State	Pop.	WU	OE	CE/RE	EC (kWh)	OEIH (kwh/inhab)
			Ambiente SAPSA				
Hermosillo	Sonora	784,342	Agua de Hermosillo	OPD	Yes (Concessioned WWTP)	94,963,292	121.074
Irapuato	Guanajuato	529,440	JAPAMI	OPD	-	11,812,284	22.311
Iztapalapa	CDMX	1,815,786	Tecnología y Servicios de Agua	Conc.	-	-	-
Juárez	Chihuahua	1,332,131	JMAS	OPD	Yes (Concessioned WWTP)	865,670	0.650
León	Guanajuato	1,436,480	SAPAL	OPD	Yes	-	-
Mérida	Yucatán	830,732	JAPAY	OPD	Yes	-	-
Mexicali (2)	Baja California	936,826	CESPM	OPD	Yes	31,042,088	33.135
Monterrey	Nuevo León	1,135,550	SADM	OPD	Yes	-	-
Morelia	Michoacán de Ocampo	729,279	OOAPAS	OPD	-	10,698,934	14.671
Naucalpan de Juárez	México	833,779	OAPAS	OPD	-	23,015,625	27.604
Nezahualcóyotl	México	1,110,565	ODAPAS	OPD	-	17,049,171	15.352
Puebla	Puebla de Zaragoza	1,539,819	Agua de Puebla	Conc.	-	-	-
Querétaro	Querétaro	801,940	CEA	OPD	Yes (Concessioned WWTP)	20,463,839	25.518
Reynosa	Tamaulipas	608,891	COMAPA	OPD	-	24,992,185	41.045
Saltillo	Coahuila de Zaragoza	725,123	AGSAL	Mixed Paramunicipal Company	-	-	-
San Luis Potosí	San Luis Potosí	772,604	INTERAPAS	OPD	Yes (Concessioned	7,237,097	9.414

Municipality	State	Pop.	WU	OE	CE/RE	EC (kWh)	OEIH (kwh/inhab)
					WWTP)		
Tijuana	Baja California	1,559,683	CESPT	OPD	-	8,124,844	5.209
Tlalnepantla de Baz	México	664,225	OPDM	OPD	-	34,095,274	51.331
Tlalpan	CDMX	650,567	AMSA	Conc.	-	-	-
Tlaquepaque	Jalisco	608,114	SIAPA	OPD	-	4,163,583	6.847
Toluca	México	819,561	AYST	OPD	-	39,430,162	48.111
Torreón	Coahuila de Zaragoza	639,629	SIMAS	OPD	-	6,946,759	10.861
Tuxtla Gutiérrez	Chiapas	553,374	SMAPA	OPD	-	3,117,413	5.633
Veracruz	Veracruz Ignacio de la Llave	552,156	Grupo Metropolitano de Agua y Saneamiento (Grupo MAS)	Conc.	-	-	-
Zapopan	Jalisco	1,243,756	SIAPA	OPD	-	26,180,707	21.050

Source: *Authors with data from INEGI (2011), CRE (2017), (CONAGUA,2012a), (CONAGUA, 2019h),(2018a pp. 99) and information shared by CESPM and JAPAY.*

NOTES:
1. Chimalhuacán has been ruled out because the 2 WWTPs that are detected within the municipality are owned by CONAGUA since they are located in the Lago de Texcoco Ecological Park and it seems that the municipal wastewater is transferred to the WWTP of Coatepec, Teotihuacán and Texcoco.
2. Although Mexicali has a photovoltaic system in the WWTP "Arenitas", it was considered as a case of replication, since it has the best PIGOO scores of the analyzed water utilities, and has a desirable potential to reduce its operational energy intensity.
3. The empty cells show that the indicator did not meet the requirements to pass to the next filter, so they are not considered for the average calculations of the following indicators
4. The clarification: "Yes (Concession)" means that some wastewater treatment plant has clean or renewable energy solutions, but it is under concession to a private company, so it is still possible to work with the remaining infrastructure operated by the OOA and therefore it passes the filter. (For more details see table 5. Summary of Water Utilities with Clean Energy Projects).

Description of Municipalities Participating in the Study

During the selection stage, a workshop was held November 13, 2020 in order to present the project to nine (9) decentralized water utilities that were interested. Only five (5) shared information on their hydraulic infrastructure, energy consumption data and derived costs. Based on our analysis, three (3) municipalities were selected for this study: Mexicali, Durango and Torreon. These municipalities showed interest and shared the necessary information to carry out an EE and RE analysis.

The following performance indicators for water utilities Waters of the Municipality of Durango (Aguas del Municipio de Durango, AMD), Mexicali State Public Services Commission (Comisión Estatal de Servicios Públicos de Mexicali, CESPM) and Municipal Water and Sanitation System of Torreón (Sistema Municipal de Aguas y Saneamiento de Torreón, SIMAS) reflect healthy financial sustainability and good water management due to their outstanding service coverage.

Table 28. Performance Indicators of AMD Durango, CESPM Mexicali and SIMAS Torreón

Indicator	AMD (Durango)	CESPM (Mexicali)	SIMAS (Torreón)
Working relationship (%)	87.61 (good)	96.85 (good)	83.8 (good)
Cost between volume produced ($/m3)	4.4 (good)	12.61 (outstanding)	9.09 (good)
Wastewater Treated Volume (%)	108.19 (outstanding)	97.15 (outstanding)	93.69 (outstanding)
Water Coverage (%)	99.48 (outstanding)	98.28 (outstanding)	99 (outstanding)
Sanitary Sewer Coverage (%)	98.6 (outstanding)	95.5 (outstanding)	97 (outstanding)
Macro measurement (%)	84.04 (good)	100 (outstanding)	100 (outstanding)
Micro measurement (%)	63.45 (good)	91.73 (outstanding)	44.24 (good)
Physical Efficiency (%)	42.65 (good)	81.83 (outstanding)	48.96 (good)
Commercial Efficiency (%)	94.05 (outstanding)	99.84 (outstanding)	79.41 (good)
Overall Efficiency (%)	40.11 (good)	81.7 (outstanding)	38.88 (good)
Consumption per capita (T6) (kwh/hab)	14.571	33.135	10.861

Source: Authors with Information from IMTA (2019), Fitch Ratings (2020b) (2020a) and S&P Global Ratings (2020)

Next, we describe the information shared by the water utilities on the hydraulic infrastructure and also detail the vulnerability to climate change and the socioeconomic situation of the municipality.

MEXICALI

The municipality of Mexicali is located in the state of Baja California, northwest of the Mexican Republic, bordering the USA. According to the 2020 Population and Housing Census conducted by the National Institute of Statistics and Geography (INEGI), Mexicali has a population of 1,049,792 inhabitants (INEGI, 2021b). The continental surface of the municipality is 14,528.3 km2, so its population density is 72.26 inhabitants/km2 (INEGI, 2021a) and concentrates 27.8% of the state's population.

Mexicali's water utility is called "Comisión Estatal de Servicios Públicos de Mexicali" (CESPM). In October 2020, the international credit rating agency, FITCH RATINGS, granted CESPM an A+ rating, a rating that assures the water utility's financial stability (Fitch Ratings, 2020a). In November 2020, CESPM was also awarded the "Gonzalo Río Arronte," a recognition given for best practices in water collection-payments. The award is granted to water utilities on an annual basis that distinguish themselves with the best technical-administrative practices in the area (Comisión Estatal de Servicios Públicos de Mexicali [CESPM], 2020).

CESPM'S HYDRAULIC INFRASTRUCTURE

Mexicali's operating agency has 122 energy consumption centers, 50 facilities for potable water service and 72 for sanitation service.

WATER

Mexicali is supplied with water from the Colorado River, "the water of the Colorado River is captured in Mexico at the diversion structure called "Presa Morelos", located in the border town of Los Algodones, Baja California. The water flows through the canals of Irrigation District No. 14, where the Benassini canal supplies two of the three water treatment plants in the City of Mexicali, Planta Potabilizadora No. 1 and Planta Potabilizadora No. 2, and the Reforma canal supplies the third, Planta Potabilizadora No. 3 (Comisión Estatal de Servicios Públicos de Mexicali [CESPM], 2019).

In the Valle de Mexicali and San Felipe localities, CESPM operates 37 potable water systems of various capacities that serve 68 localities. Sixty-five percent of these systems are supplied with water from the canal and 35% with water from underground (wells) (CESPM, 2019). According to the information shared by the Water and Sanitation Sub-Directorate, CESPM operates:

- 8 Water Treatment Plants: 3 Main Water Treatment Plants, 5 smaller Water Treatment Plants in Mexicali.
- 2 Monitoring Stations, 1 Rechlorination Station, 1 Flow Meter, and 1 Dosing Plant in Mexicali.

- 37 potable water systems to supply the towns of Valle de Mexicali and San Felipe: 28 treatment systems for Valle de Mexicali and for San Felipe only 6 wells, 2 tanks of 5,000 m3 and 1 pumping plant.

Table 29. Water Treatment Plants in the City of Mexicali

Water Treatment Plant Name	Purification Process	Installed Capacity (l/s)	Flow Treated (l/s)
Mexicali 1. Río Culiacán	Conventional Clarification	1800	298
Mexicali 2. Col. Calles	Direct Filtration	2500	1843
Mexicali 3. Xochimilco	Conventional Clarification	1250	679
Miguel Hidalgo	Direct Filtration	20	0.6
Hipólito Rentería	Conventional Clarification	18	5.4
Cerro Prieto 6	Direct Filtration	5	0.8
Benito Juárez	Direct Filtration	5	0.5
Xochimilco Fidum	-	-	-
	TOTAL	5,598	2,827.3

Source: Authors with information shared by CESPM and from the Inventory of Municipal Water Treatment and Wastewater Treatment Facilities (CONAGUA, 2020a).

WASTEWATER

The installed capacity for wastewater treatment is 2,423 liters per second (lps), which treats a flow of 2,290.6 lps. Of the treated water, 80.6% is reused for sale to thermoelectric plants (Termoeléctrica La Rosita and Termoeléctrica de Mexicali), sale to Electra Estrella de Oro, the purple line project (landscape irrigation), environmental compensation, and internal irrigation of green areas at the Zaragoza, Arenitas, and CETYS WWTPs (Domínguez, J., personal communication, January 2021). According to information shared by CESPM's Wastewater Department, it operates:

- 11 Wastewater Treatment Plants (WWTPs), 3 WWTPs located in the city of Mexicali and 8 WWTPs serving the surrounding towns of Valle de Mexicali and San Felipe. The treatment processes used are lagoon systems with partial aeration and activated sludge systems.
- In addition, the operator reports the consumption of a house of oxidation lagoons.
- There are 2 WWTPs that treat water in Mexicali using activated sludge systems, but they are not operated by CESPM, the "Instituto Tecnológico de Mexicali" (7 lps) and UABC (10 lps).
- 45 wastewater pumping stations (CBAR), 22 in the City of Mexicali, 17 in the Mexicali Valley, and 6 in San Felipe. These convey wastewater from the

sewage system to a higher level point (manhole, pressure breaker box, collector) and are directed again by gravity to the Pumping Plants.

- 14 Wastewater Pumping Plants (PBAR) for the City of Mexicali. They receive large volumes of wastewater and subject it to a pretreatment system to remove floating and sedimentable solids and bad odors before it is sent to the respective WWTPs.

Table 30. Wastewater Treatment Plants Operated by CESPM

Wastewater Treatment Plant Name	City	Treatment Process	Installed Capacity (l/s)	Flow Treated (l/s)
Zaragoza	Cd. Mexicali	Partial Aeration Lagoons	1,300	1158
Las Arenitas	Cd. Mexicali	Partial Aeration Lagoons	840	992
CETYS	Cd. Mexicali	Activated Sludge System	7	3.4
Alfredo V. Bonfil	Valle	Activated Sludge System	6	0.3
Algodones	Valle	Lagunar System	20	18.7
Ciudad Morelos	Valle	Lagunar System	30	18.8
Gpe. Victoria (km 43)	Valle	Lagunar System	70	38.6
Estación Coahuila	Valle	Lagunar System	20	9.7
La Puerta	Valle	Activated Sludge System	6	4.1
Oaxaca	Valle	Activated Sludge System	4	2.9
San Felipe	San Felipe	Lagunar System	120	44.1
		TOTAL	2,423	2,290.6

Source: Authors with information shared by CESPM and from CONAGUA (2020a)

Figure 10. Location of main WWTPs and PBARs in Mexicali

Source: *Image shared by CESPM*

DURANGO

The municipality of Durango (officially, Victoria de Durango) is located in the state of the same name, in the north of the Mexican Republic. It is the most populated and extensive at the state level, with a population of 688,697 inhabitants (INEGI, 2021b), an extension of 9,285.4 km2, a population density of 74.17 inhabitants/km2 (INEGI, 2021a) and 37.6% of the state's population.

The Durango Water Operating Agency is called "Aguas del Municipio de Durango" (AMD), which is a Decentralized Public Agency that provides drinking water, sewerage and sanitation services to the city of Durango, promoting sustainable development.

AMD'S WATER INFRASTRUCTURE

The water utility from Durango shared information on 128 energy consumption centers. 115 facilities for potable water service and 11 for sanitation service, offices and hut of the Oriente wastewater treatment plant.

WATER

The city of Durango is supplied with drinking water from the Guadiana Valley aquifer by deep water wells. Drinking water is distributed to the nearly 80 neighborhoods in the city through storage tanks and directly from the wells that feed the distribution network (CONAGUA, 2014).

According to information shared by the Water Utility AMD, it operates:

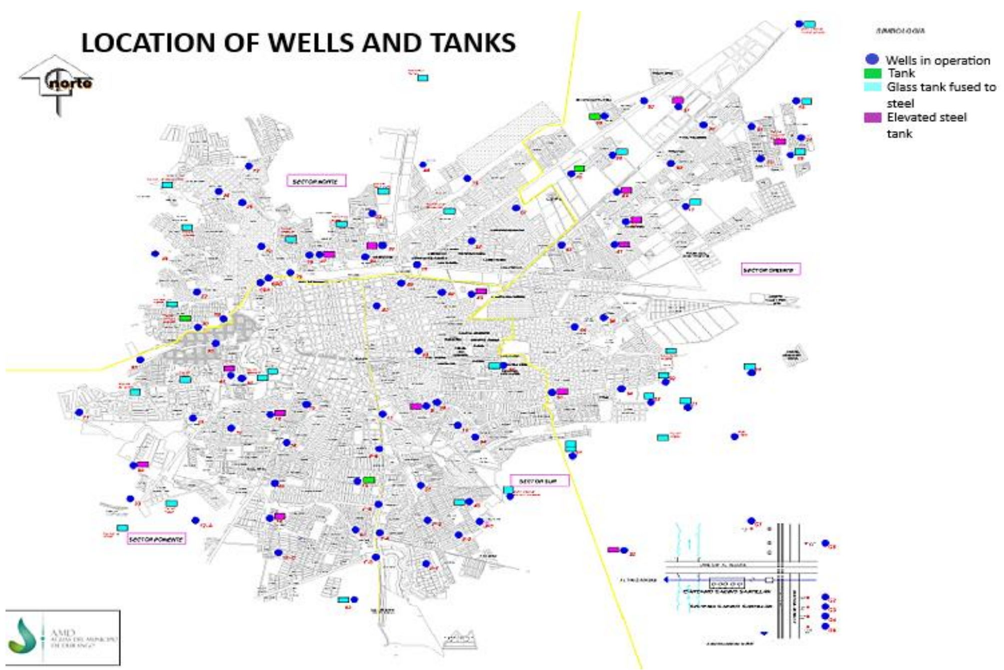
- 100 deep wells for potable water
- 7 pumping sumps for potable water (cárcamos)
- 8 storage tanks[56]

WASTEWATER

The installed capacity for wastewater treatment is 2,800 liters per second (l/s), which treats a flow of 1,870.5 l/s. According to the information shared by the AMD Water utility, it operates:

- 5 Wastewater Treatment Plants (WWTP) using Activated Sludge Systems and Facultative Lagoons treatment processes.
- 5 Wastewater pumping sumps, which are named Poblado 5 de mayo, Poblado 20 de noviembre, Colonia 20 de noviembre, Cárcamo México and, Poblado 15 de octubre.
- 1 drain water drainage sump (Nuevo Durango)

Figure 11. Location of water wells and storage tanks from AMD



Source: 2014 Drought Mitigation and Preventive Measures Program for the city of: Victoria de Durango, Durango (CONAGUA, 2014)

[56] These 8 storage tanks have direct service from the CFE, however, AMD operates 39 tanks in total (22 belong to the load point of the deep well system and 9 are out of operation)

Table 31. Wastewater Treatment Plants operated by AMD

Wastewater Treatment Plant Name	Treatment Process	Installed Capacity (l/s)	Flow Treated (l/s)	Main Collectors
Oriente	Facultative Lagoons (Biological Process)	2000	1450	Canelas, Sahuatoba, Ferrocarril, Industrial, San Gabriel, 20 De Noviembre Y Dolores Del Rio
Sur	Activated Sludge	600	350	Tapias 1 Y 2, Ferreria, Durango Nuevo, Pastor Roaix, Interseccion Sur, Pueblito, 5 Sur Y Acequia
Cristóbal Colón	Activated Sludge	150	50	Cristobal Colon, Milenio Y Subcolector Providencia
Del Parque Guadiana	Activated Sludge	30	20	Subcolector Silvestre Revueltas
Dalila	Activated Sludge	20	0.5	Colector Rio Dorado
	TOTAL	2,800	1,870.5	

Source: Authors with information shared by AMD.

TORREON

The municipality of Torreon is located in the state of Coahuila Zaragoza in northeastern Mexico. It is part of the Comarca Lagunera along with the neighboring cities of Matamoros in the same state and Ciudad Lerdo and Gómez Palacio in the state of Durango.

It is the second most populated municipality in the state with a population of 720,848 inhabitants (INEGI, 2021b). The continental surface of the municipality is 1282.7 km2, so its population density is 562 inhabitants/km2 (INEGI, 2021a) and concentrates 23% of the state's population.

Torreon's water utility is called "Sistema Municipal de Aguas y Saneamiento de Torreón" (SIMAS), which is a Decentralized Public Agency whose mission is to provide water service reaching the highest quality levels generating a healthier life for the community.

HYDRAULIC INFRASTRUCTURE OF SIMAS

Torreon's water utility shared information on 194 energy consumption centers, 142 drinking water service facilities, 4 WWTPs, 32 wastewater pumping facilities and 16 rainwater drainage sumps.

WATER

The municipality of Torreón is supplied with groundwater from the "Principal de La Comarca Lagunera" aquifer and its main sources of recharge are the Nazas and Aguanaval rivers.

99.87% of the water for public supply comes from underground sources, which implies low quality and high contamination caused by the existence of harmful minerals (e.g. arsenic) in low groundwater levels (Gobierno Municipal de Torreón, 2018). According to SIMAS, 2,500 l/s of drinking water are extracted, 11% is for industrial uses, while the remaining 89% is for domestic, commercial, public services, etc. (Gómez, J., personal communication, january 2021).

SIMAS has 94 deep well pumping units and records that 87% of energy consumption is used for this purpose. According to the information shared by SIMAS operates:

- 94 water wells
- 4 drinking water pumping stations (private wells in Santa Fe, Las Flores, Fracc. San Luciano and Clarificadora).
- 44 storage tanks

In order to reduce energy consumption for the extraction of drinking water, to opt for surface sources and to have more and better quality water, a project is currently being developed to distribute water from the "Francisco Zarco" dam to the municipalities of Torreón, Gómez Palacio and Lerdo de Tejada. It is in the bidding process to assign the developer company and it is expected that this project will start operating in 2 years (Gómez, J., personal communication, January 2021).

WASTEWATER

The installed capacity for wastewater treatment is 1,925 liters per second (lps), which treats a flow of 1,194 lps.

The treated wastewater is reused for agricultural irrigation and industrial purposes. SIMAS negotiated with the CFE to change the tariff for the wastewater pumping stations to a tariff for agricultural irrigation in Medium Voltage (RAMT), which has reduced the costs for this concept (Gómez, J., personal communication, january 2021).

According to the information shared by the SIMAS Operating Agency, it operates:

- 3 Wastewater Treatment Plants (WWTP) that use Oxidation Lagoon and Activated Sludge Systems treatment processes. The Rancho Alegre WWTP has 2 other facilities: a Parshall Canal and a pumping station for the return of treated water.
- 48 wastewater sumps (16 rainwater drainage sumps)

Table 32. Wastewater Treatment Plants Operated by SIMAS

Wastewater Treatment Plant Name	Treatment Process	Installed Capacity (l/s)	Flow Treated (l/s)	Main Collectors
Rancho Alegre	Oxidation lagoons	1900	1187	Los Rodriguez, Allende, Juarez, La Perla, Zaragoza Y Oriente
Bosque Urbano	Activated Sludge	20	5.42	Los Rodriguez Y Bravo
Fundadores	Activated Sludge	5	1.64	Bravo
	Total	1,925	1,194.06	

Source: Authors with information shared by SIMAS.

WATER RATES

Water rates in Mexico are classified according to the type of user and to cost redistribution mechanisms through subsidies. The tariffs generally consist of fixed charges and variable charges depending on the volume used and charges for sewerage and wastewater treatment. The higher the water consumption, the higher the price per cubic meter (CONAGUA, 2019e).

The rates are established and updated by the water utility, while the instance that authorizes them varies according to what is marked in the state water laws of each federative entity, this can be the City Council (through a council session), the corresponding State Water Commission or the State Congress (CONAGUA, 2019e).

- In the State of Coahuila de Zaragoza the board of directors (administrative and management body of the Water Utility) studies and approves the rates for the services provided.
- In the State of Durango, the State Water Commission will approve the average rates calculated, as well as the congruence between the average rates and the corresponding rate structure.
- In the State of Mexicali, rates are reviewed and authorized annually by the State Congress. The rates are published in the income law of the State of Baja California.

Table 33 shows the rate for middle class domestic users to find out the water service charges for the 3 allied municipalities, these fees and rates are updated monthly. The charges can vary according to the type of user and discounts can be applied to them as support for people with socioeconomic vulnerability or as an incentive to reduce the consumption of the resource and to be current with the payment of the service.

Table 33. Monthly water rate for middle-class domestic users in Mexicali, Durango and Torreón

Municipality	Fixed fee (MXN)	Variable charge for surplus of 30 m3 consumed (MXN)	Variable charge for sewerage and sanitation (% of the concept of drinking water service)
Mexicali	65.17 (0-5 m3)	6.59	For commercial, industrial and agricultural users only
Durango	166.27 (0-10 m3)	6.89	Sewerage: 30% Sanitation: 9.9%
Torreón	120.42 (0-10 m3)	15.96	Sewerage: 25% Sanitation: 31%**

Source: Authors with data from Gobierno del Estado de Baja California (2020), SIMAS Torreón (2021) and H. Congreso del Estado de Durango (2021).

Notes: * The table reflects the monthly rate for middle-class domestic users

** In Durango, the sanitation concept is charged after the range of 30 m3 consumed

CLIMATE CHANGE VULNERABILITY OF THE MUNICIPALITIES

In order to analyze the possible difficulties that the decentralized water utility's present to guarantee a continuous and quality service, in this section the degree of water pressure is reported at different levels of measurement, from the degree of pressure of the Administrative Hydrological Region (RHA) to which it belongs to the sub-basin closest to the municipality.

The municipality of Mexicali belongs to the RHA "I Península de Baja California", Durango to the RHA "III Pacífico Norte" and Torreón to the RHA "VII Cuencas Centrales del Norte". The degrees of water pressure at the regional level can be consulted in the National Water Information System (SINA), the RHA I and VII have a high degree of water pressure and the RHA III medium to high (CONAGUA, 2019b).

To obtain the degree of water pressure at the state level, data were extracted from the concessioned volumes of water by state (CONAGUA, 2019g) and data on renewable water per capita to 2019 (CONAGUA, 2019a), the results showed that Baja California has a very high degree of water pressure, Coahuila high and Durango low.

The results of AQUEDUCT Water Atlas database, an Atlas that measures a homologous indicator (water depletion), are extracted for the closest sub-basins: "Lago Saltón" in Mexicali, "San Pedro" in Durango and "Aguanaval" in Torreón. Table 34 shows a summary of the data:

Table 34. Degree of water pressure at different levels (RHA, State and Hydrological Sub-basin)

Municipality	Measure level	Degree of water pressure
MEXICALI	RHA level (I Península de Baja California)	High (91.9%)
	State level (Baja California)	Very high (114.4%)
	Hydrological Sub-basin level (Lago Saltón)	High (50-75%)
DURANGO	RHA level (II Pacífico Norte)	Medium-high (40%)
	State level (Durango)	Low (11.9%)
	Hydrological Sub-basin level (San Pedro)	Low-medium (5-25%)
TORREÓN	RHA level (VII Cuencas Centrales del Norte)	High (47.5%)
	State level (Coahuila)	High (63.8%)
	Hydrological Sub-basin level (Aguanaval)	Low (5%)

Source: Authors with data from SINA (CONAGUA,2019a), (CONAGUA, 2019b), (CONAGUA, 2019g) and (WRI, 2019)

Regarding hydrometeorological phenomena, the CENAPRED's Declaratory Consultation System (National Center for Disaster Prevention (CENAPRED), 2021):

- In Mexicali: 6 declarations between 2001 and 2018. The phenomena with the greatest presence were tropical cyclones and extreme temperatures (2 each). The year 2018 was the most influential with 4 declarations.
- In Durango: 55 declarations between 1999 and 2020. The phenomena with the greatest presence were rains (atypical, severe and torrential) with 21 declarations. The years with the greatest influence were 2016 and 2018 with 6 declarations each.
- In Torreón: 17 declarations between 2000 and 2018. The phenomena with the greatest presence were rains (atypical and severe) with 8 declarations. The year with the greatest influence was 2018 with 5 declarations.

The municipalities present a medium-high degree of water pressure, where the specific hydrometeorological phenomena of each area are more repetitive and intense, so that the water utilities directly face the climatic challenges that affect the availability and quality of water for human consumption.

Description of the Socio-Economic Situation of the Municipalities

This section seeks to link the socioeconomic situation of the municipalities with the vulnerability of their population and their availability to obtain basic services such as water. In addition to evaluating the prosperity of the municipality based on the Basic Index of Prosperous Cities (CPI, for its acronym in English) of UN-Habitat. Mexicali, Durango and Torreón have a very low marginalization index, a very low social backwardness index and a percentage of poverty situation of 27.5%, 32.3% and 26.2% respectively.

Table 35. Socio-economic Indicators for Mexicali, Durango and Torreón

Municipality	Indicators	Value
MEXICALI	Marginalization index (1)	Very low (-1.648)
	Social backwardness index (2)	Very low (-1.34)
	Percentage of poverty situation (3)	25.7%
	Percentage of the population living in extreme poverty (3)	1.7%
DURANGO	Marginalization index (1)	Very low (-1.585)
	Social backwardness index (2)	Very low (-1.31)
	Percentage of poverty situation (3)	32.3%
	Percentage of the population living in extreme poverty (3)	0.8%
TORREÓN	Marginalization index (1)	Very low (-1.722)
	Social backwardness index (2)	Very low (-1.4)
	Percentage of poverty situation (3)	26.2%
	Percentage of the population living in extreme poverty (3)	2.8%

Source: Authors with data from CONAPO (2015), CONEVAL (2015) and INEGI (2015).

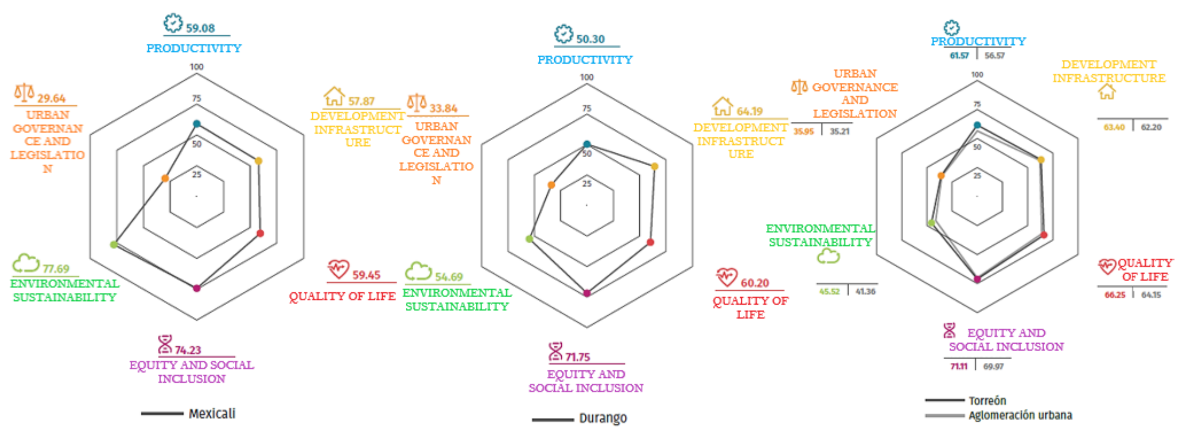
(1) CONAPO, 2015a (2.) CONEVAL, 2015b (3.) CONEVAL, 2015a

The data collected shows that the socioeconomic situation of the municipalities is stable since they have very low levels of marginalization and social backwardness, however poverty indicators still prevail, since according to data from INEGI (2015) 23.1%, 33.5% and 31.8% of the The population of Mexicali, Durango and Torreón respectively earn less than 2 times the minimum wage.

The CPI reports that the three municipalities have moderately weak prosperity. The environmental sustainability scope is relatively strong for Mexicali (77.69) but low for Durango (54.69) and Torreón (45.52) (Programa de las Naciones Unidas para los Asentamientos Humanos [UN-Habitat], 2018a,b,c).

Also the CPI remarks that the sub-dimension of proportion of renewable energy generation[57] reflects low ratings for Durango and Torreón, which gives an indication of the relevance of adopting policies and actions to strengthen this sector , while Mexicali with better results presents opportunities to consolidate renewable energy solutions (UN-Habitat, 2018a,b,c).

Figure 12. Results by Dimension of the Basic City Prosperity Index



Source: *UN-Habitat (2018a), (2018b) and (2018c)*

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[57] Geothermal energy, photovoltaic solar, thermal solar, tide, wind, industrial or municipal waste, solid primary biofuels, biogas, biofuel, biodiesel, other liquid biofuels, primary biofuels and unspecified waste, and charcoal as part of the total of the electrical production. Indicator calculated with data from CFE of 2015 (Gross and net monthly generation, by technology and municipality) and of SENER of 2016 (National Inventory of Clean Energy [INEL]. Gross generation from January to December 2016) (ONU-Habitat, 2018a,b,c).

Appendix 2. RE Opportunities Research Design: Data, Methodology and Assumptions

This project set out to help water treatment facilities in Mexico evaluate and, where viable, carry out substantive energy efficiency and renewable energy projects.

To do this, an agreement to dedicate staff time and provide site specific electricity data was requested from over a dozen water treatment organizations in Mexico in 2020. With the support of Instituto Nacional de Ecología y Cambio Climático (INECC) and the willing participation of three water utilities serving over nearly 3 million people, limited but critical data was acquired from Data provided by Municipalities of Durango, Mexicali, and Torreón. The data encompassed over 200 sites, the study only included sites with data and demand over 150 kWh per month. In addition, where electrical usage or cost data was missing or incomplete, cases (meters) were not included in the RE section. In Mexicali, for example the following load centers (meters) were not included:

"BENITO JUÁREZ" PLANT, "CERRO PRIETO 6" PLANT, "CIUDAD VICTORIA" PLANT, "COL CARRANZA" PLANT WELL, "GÓMEZ MORÍN" PUMPING SUMP, "LÁZARO CÁRDENAS LA 28" PLANT, "LOS GAVILANES" PUMPING SUM, "MADERO" PUMPING SUMP,"RANCHO EL CHIMI EJ., DURANGO" PUMPING SUMP, "SAN FELIPE 6" WELL, "SOLIDARIDAD" PUMPING SUMP, "VALLE DE GUADALUPE" PLANT WELL, DOSING PLANT POT-1, FLOW METER POT-2 BOX A, MONITORING STATION KM 46, MONITORING STATION KM 46, PBAR-12, and RE CHLORINATION STATION.

For Torreón sites that were labeled by the municipality as 'non-sump-pumps' were the focus of the mid-range load center analysis. Of the 94, 10 were dropped for insufficient data, leaving: 84 load centers. Without technical (design and engineering) site evaluations across all the sites, which was not possible to conduct due to the COVID-19 pandemic, the analyses presented in this document had to make many assumptions and generalizations to illustrate certain points and provide tables with numbers. Tables 16-18 relied on the following assumptions:

Table 36. Assumptions for RE

m^2/MW	12
Exchange rate MXN:USD	20

Source: Authors

Table 37 assumes a prespecified discount to utility rates with an RE PPA, no annual escalation in electricity prices, and there is no financial discount rate applied. In addition, the following assumptions are applied in the generation of figures for the Table.

Table 37. Discounts for RE

Discount to Utility	Value
<500 KW	10%
5-10 MW	15%
30 MW	20%

Source: Authors

For Table 38 it is assumed that costs are lower as RE system sizes increase ($/KW), production (kWH) is better for ground mounted or off-site RE systems, and utility rates ($/kWh) are lower. The assumption are enumerated here:

Table 38. Assumptions for RE

Load Centers	Installed Cost ($MXN/KW)	kWh	$/kWh
Smallest	$20,000	1,552	2.4
Small	$18,000	1,552	2.1
Medium	$16,000	1,695	1.9
Large	$14,000	1,940	1.6

Source: Authors

This discount rate used is 10%. The methodology utilizes basic accounting principles for determining investments, costs, revenue, and discounted cash flows. It is provided in this report for illustrative purposes only.

The formulas used for calculating the Net Present Value and Internal Rate of Return of the solar PV modules are listed on the next page.

$$NPV = \sum_{t=0}^{N} \frac{NCF_t}{(1 + i_t)^t}$$

Where:

NPV = Net Present Value

NCF = Net Cash Flow of a period

i = Discount Rate or Interest Rate

N = Total Number of Periods

t = Period in which the Cash Flows occur

$$IRR = \sum_{t-1}^{t} \frac{C_t}{(1+r)^t} - C_o$$

Where:

IRR = Internal Rate of Return

Ct = Net Cash Inflow during the period

r = Discount Rate

t = Number of periods

Co = Initial Investment (Total)

Appendix 3. Roadmap for implementing EE and RE solutions for water utilities in Mexico

Plan Act Check Do – Energy Management Systems ISO 50001

Energy Management Systems are implemented in any type of organization with the objective of establishing an energy policy that tracks and improves energy performance. The ISO 50001 is based on the continuous improvement cycle: Plan – Act – Check – Do.

Water utilities in Mexico would greatly benefit from implementing an EMS because, as previously mentioned in Section 3.3, electricity is one of the main operational costs. The new tariff scheme and renewable energy procurement options present some interesting opportunities for water utilities. New business models are arising: users need to be able to make decisions smartly and consider what is best for them. There are no right or wrong answers, nor permanent or absolute solutions that will work every time. Thus, an EMS provides enough flexibility and guidance for organizations to adjust their strategy, constantly improving and clearly establishing a path to follow.

The following roadmap intends to provide a series of steps and considerations to consider when implementing energy efficiency or renewable energy solutions in water and wastewater facilities in Mexico.

The ISO 50001 establishes the PACD cycle as follows:

Plan: Conduct an energy revision for establishing a consumption baseline, key performance indicators, objectives, goals, and action plans needed to reach results that derive on energy performance improvements. This must be aligned with the energy policy of the organization.

Act: Carry out the action plan.

Check: Keep track of processes and inform results.

Do: Take actions to improve energy performance and the EMS.

Table 39. Roadmap

Step	Objective	Description	Comment
Plan	*Establish an internal team*	Water utilities need to assemble an energy team that includes directors, managers, and technical personnel to establish an energy policy, KPIs, and actions that will be implemented. It is common for these teams to be integrated by the General Director, the Finance area, the Operations area, and the Purchasing department.	One of the requirements for water utilities (Mexicali, Torreón and Durango) to be supported was to set up an internal working group with different areas and levels.
	Establish an energy policy	Water utilities need to set goals within a certain timeframe to achieve energy reductions or improvements.	In this case, the energy policy was anchored on the mitigation goal for the Waste Sector established in Mexico's NDC. Thus, the reduction and decarbonization of energy consumption result in a reduction in GHG emissions. However, the objectives for each water utility were different: Torreón focused on water pumping, Mexicali on energy efficiency measures for its 10 major consumption points, and Durango explored options across all its processes. All of them aimed at reducing their electricity consumption, as well as implementing renewable energy solutions when possible. Meetings were carried out with water utilities to know their interests and needs.
	Energy calculations: baseline and data collection	Build a database with historical information (at least from a year back) with details of operating hours, capacity per equipment, per load point, and annual capacity. The more granularity to the data, the better. Make sure it reflects how consumption changes across hours, days and months. This is important to establish what "normal" increments or spikes look like, and what falls out of the range.	The three water utilities had a very good registry of their electricity consumption, with historical data and major consumption points identified, as well as lists of technical equipment. However, because the COVID-19 pandemic made it impossible to conduct on-site visits, solutions and analyses could only be done at a high level with the provided data.
	Establish KPIs	Depending on the priorities of the organization, indicators must be established. If the goal is energy efficiency, then indicators must track energy	For the purpose of comparison and benchmarking, the selected KPIs were kWh/liter, tCO2/MWh, MXN/kWh and kWh/year.

		consumption; if it is decarbonization, then emissions per kWh must be measured and so on. Other indicators include cost per kWh or kWh per year.	
	Planning for energy performance improvement	With a clear goal established, dates and activities must be set. If you plan on implementing any RE solutions together with EE, make sure to take into account the reductions in consumption when signing a PPA or when sizing an on site power plant.	The actions presented in this report reach up until here. EE measures and RE solutions are presented for water utilities according to the provided data and goals.
Act	*Registry of actions done*	Have written proof of the actions taken related to the established plan.	
	Energy services, products and equipment acquisition	Launch an RFP with the decisions made during the Plan phase. Include: annual consumption, average cost per kWh, number of interconnection points to the grid, total capacity, location, period for contracting, legal requirements, guarantees and conditions for cancelling the contract, minimal requirements for the energy (type of technology, tariff price, type of tariff, etc). For energy efficiency solutions, guarantees of reduction in consumption, remote or on site monitoring, type of equipment to install (controllers, sensors, etc), guarantees and contract period. When purchasing equipment, make sure to verify it complies with local legislation and has an international certification.	
	External audit for verification	Most developers or ESCOs will require to conduct on site visits.	
Check	*Track, Measure and Analyze*	Keep track of the established KPIs during the implementation phase, as well as measures taken to guarantee changes can be attributed to the planned actions and modifications. SCADA systems are particularly helpful for this; water utilities should consider implementing one.	

	Corrective and preventive actions	If anomalies are detected during the process, actions must be taken to determine their origin and, if possible, correct them.
Do	*Inform results to team*	Once the steps established in the action plan are finished, the KPIs are updated and results are presented to the team.
	Adjust and establish new action plan	A new action plan must be designed and aligned to the organization's energy policy.

Source: *Authors*

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Glossary

Activated sludge system: It is a wastewater treatment process that is based on the use of microorganisms (especially facultative heterotrophic bacteria), which grow in wastewater, converting dissolved organic matter into simpler products such as new bacteria, carbon dioxide and water. It is a secondary or biological treatment and is the most used both municipally and industrially.

Aeration system: Aeration brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulfide, and volatile organic chemicals (VOCs). Aeration is often the first major process at a treatment plant.

Carbon footprint: The amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, agency, etc.

Clean energy: Clean energies are those sources and processes for generating electricity whose emissions or waste, when any, do not exceed the thresholds established in the regulatory provisions issued for this purpose.

Consumptive use: Volume of water of a certain quality that is consumed when carrying out a specific activity, which is determined as the difference in the volume that is extracted, less the volume that is discharged.

Conventional Clarification: Process to purify surface waters with high turbidity, color and / or microorganism values. The water treatment train is integrated with the rapid addition and mixing of chemical reagents, flocculation, sedimentation, filtration and disinfection.

Direct filtration: Treatment method by which water is passed through granular media that remove contaminants. First use a chemical coagulant (such as iron or aluminum salts) and then stir the mixture, inducing the union of the small particles in suspension to form larger lumps or “flocs” that are easier to remove and finally pass the water through filters.

Drinking/Potable water (Agua Potable): Water used for domestic purposes and personal hygiene, as well as for drinking and cooking; whose microbial, chemical and physical characteristics meet WHO (World Health Organization) guidelines or national standards for drinking water quality.

Electric Rate: Electricity rates are specific provisions that contain the fees and conditions that govern electricity supplies and are officially identified by their number and / or letter (s) according to their application. CFE has different electricity rates, divided according to the type of end user, which also depend on an established regionalization.

Energy: the power from something such as electricity or oil, which can do work, such as providing heat, light, chemical transformation, etc.

Energy efficiency: It refers to the set of solutions that improve energy intensity (total energy required to supply a certain volume of water in a specific location), consisting of improving the equipment and technology of the water extraction, treatment and distribution systems.

Facultative Lagoons/Ponds: These earthen lagoons are usually 1.2 to 2.4 m (4 to 8 feet) in-depth and are not mechanically mixed or aerated. The layer of water near the surface contains dissolved oxygen due to atmospheric reaeration and algal respiration, a condition that supports aerobic and facultative organisms. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organisms. The intermediate anoxic layer, termed the facultative zone, ranges from aerobic near the top to anaerobic at the bottom.

Fossil Fuels: They are non-renewable resources that come from the decomposition of the geological remains of combustible organic materials, and that can be used for the provision of energy. (coal, oil, natural gas).

Greenhouse gases (GHG): They are gases emitted in a natural and anthropogenic way (emitted by human activity) whose presence contributes to the greenhouse effect. The six gases listed in the Kyoto Protocol are: carbon dioxide (CO2); methane (CH4); nitrous oxide (N2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF6).

Hydrological-Administrative Regions: Regions formed by groupings of hydrological basins, considered as the basic units for the management of water resources in which CONAGUA performs its functions through basin organizations.

Hydrological Basins (RH): Areas formed by groupings of hydrological sub-basins, whose surface runoff flows entirely through a series of streams, rivers and eventually lakes towards the sea through a single mouth, estuary or delta.

Hydrological Sub-basins: Land area whose surface runoff flows entirely through a series of streams, rivers and, eventually, lakes towards a certain point of a watercourse (generally a lake or a confluence of rivers).

Mexico's Clean Energy Certificates (CEL's): CELs provide a way for utilities and organizations to buy their way out of emission reductions associated with their energy consumption. As of January 2021, CEL policies and market practices in Mexico are being reshaped in the courts -with some cases including constitutional challenges. The associated uncertainty has led to an effective pause in Mexico's CEL market. For organizations that have poor on-site installation conditions or financing ability (credit worthiness), with unforeseen positive changes in policy, CELs may become the least cost approach for achieving corporate or mandated GHG emissions reductions.

Potable Water: Also known as drinking water, comes from surface and ground sources and is treated to levels that meet state and federal standards for consumption. Water from natural sources is treated for microorganisms, bacteria, toxic chemicals, viruses and fecal matter.

Power Factor: Power factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). Apparent power, also known as demand, is the measure of the amount of power used to run machinery and equipment during a certain period. It is found by multiplying (kVA = V x A). The result is expressed as kVA units.

Power Purchase Agreement (PPA): Electric Coverage Contract to procure energy from a Qualified Supplier.

Pumping Systems (Sistemas de bombeo): Devices used to lift and extract water from low to high point, from surface water, groundwater, or from reservoirs to distribution systems. They can be powered by various energy sources (electricity, solar, fuel, wind, etc.).

Renewable energy: Obtained from a constantly available stream of resources, such as solar and wind, which don't emit carbon dioxide and other greenhouse gas emissions in their production that contribute to global warming.

Renewable water: Maximum amount of water that is feasible to exploit annually in a region, that is, the amount of water that is renewed by rain and water from other regions or countries (imports). It is calculated as the mean annual internal surface natural runoff, plus the total annual recharge of aquifers, plus inflows minus outflows of water to other regions.

Oxidation/Storage lagoons: Lagoons are pond-like bodies of water or basins designed to receive, hold, and treat wastewater for a predetermined period of time. If necessary, they are lined with material, such as clay or an artificial liner, to prevent leaks to the groundwater below.

Wastewater (Agua Residual): Waters from productive, industrial processes or human consumption that acquire different characteristics from those it had when it was considered potable water. After treatment, they can be converted into reclaimed water that can be reused if they meet the appropriate quality criteria for each type of use.

Water Rate Billing: It is the table authorized for fixing the payment for each type of user, for drinking water, sewerage and sanitation, considering, where appropriate, the level of consumption and the prices per unit of service that each user must pay.

Water Storage Tank: A water storage tank collects water and stores it for later use and timely access.

Water Treatment Plants (PP): Complex that is responsible for subjecting the surface or underground water of a river, or any other reservoir, to various processes in order to ensure that it is suitable for consumption and use in the daily activities of the population.

Wastewater Treatment Plants (PTAR): It is a facility where Wastewater is treated to remove pollutants and other physical and chemical qualities, to make it a water without risks to health and / or the environment by disposing it in a natural receiving body (sea, rivers or lakes) or for reuse in other activities

Wastewater Pumping Plants (PBAR): Facilities that receive large volumes of wastewater and submit it to a pretreatment system to remove floating and sedimentable solids and bad odors and then be directed to the respective WWTPs.

Water utility (Organismo Operador de Agua): Public, private or mixed organization in charge of the obligations of a municipality to provide the public services of water, sewage, treatment and disposal of wastewater.

Water Well: Is an excavation or structure created in the ground to access groundwater, drawn by pumps, in underground aquifers. Wells can vary greatly in depth, water volume, and water quality.

Note: The glossary is a compilation of various sources, in order to define the concepts used in the document. Therefore, they do not constitute definitions with legal force.