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Market opportunities on Circular Economy in Mexico

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Market Opportunities on Circular Economy in Mexico

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The purpose of this study is to identify business opportunities for EU companies in key Circular Economy sectors in Mexico, notably in the fields of: waste management, waste water and waste energy. This study was presented in the Circular Economy Mission held in Mexico City from the 24th to the 26th of April.

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1. EXECUTIVE SUMMARY

Current Situation in Mexico

Mexico is now the world's 11th largest economy and its development is putting it on course to be the 8th largest. However, this development has come at a significant cost where waste production accounts for more than 44 million tons per year (0.86 Kg per person) and this number is expected to reach 65 million by 2030[1]. Furthermore, approximately only 9.6% of the solid waste generated in Mexico's cities is recycled each year (SEMARNAT, 2010), where 70% of that urban solid waste ends up in landfills (INEGI, 2016). With regards to food waste it is estimated that 34.5% of the country's total food production is wasted. This wasted food would be enough to feed 7.4 million Mexicans (World Bank, 2017). Furthermore, since 2008, Mexico has undergone a series of structural reforms to promote the use of waste as an energy source, while incentivising the reduction of GHG emissions. In 2015, the Energy Transition Law (LTE) was signed into law, stating that 25% of the energy generated must come from clean energy sources by 2018, 30% by 2020, and 35% by 2024 (DOF, 2015). To reach these objectives, the barriers that limit the exploitation of renewable energy sources must be overcome. In 2013, energy generated from waste only contributed to 1.39% of the total Mexican energy consumption (SENER, 2014). However, the energy potential from residual biomass in 2016 was estimated at 1,070 PJ, corresponding to 12% of the total energy mix.

Related to Mexico's production, the water sector demonstrates significant water stress mainly related to climate, demography and industrial volume use. The level of water stress is an indicator for improved water management, wastewater treatment and reuse technologies. The problems related to urban wastewater are further compounded by the lack of maintenance of the urban wastewater treatment technologies. For instance, 555 wastewater treatment plants (19.2% of a total of 2892 plants) were out of operation in 2015 (Conagua, 2014). Furthermore, the technologies used in urban wastewater treatment plants that are in operation in Mexico are antiquated.

Herein lay significant opportunities for investment and improvement in moving these sectors towards a circular economy.

Circular Economy

The EU is a recognised and demonstrated global leader in circular economy and any new technology, policy, legislation, reform, acceptance or change made in the EU can be mirrored to Mexico's benefit.

A circular economy is 'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised'. European Commission 2018

With regards to Mexico's circular economy initiatives, the country is moving forward with policy, reform and legislation to bring change to sectors that are lagging behind. Thus, the country is looking to bring

[1] https://www.gob.mx/cms/uploads/attachment/file/435917/Vision_Nacional_Cero_Residuos_6_FEB_2019.pdf

the circular economy concept to Mexican industries to bring about change, as these current initiatives show:

- ✓ *Pacto por México*: Reforms related to trade openness, foreign direct investment, integration into global value chains, and innovation incentives, these have also boosted exports, notably within the car and truck industries.
- ✓ *National Programs for the Prevention and Integral Management of Waste*: seeks to promote the valorisation of waste and to minimise the impact on the environment and particularly to human health.
- ✓ *Energy Transition Law*: regulates sustainable electricity use.
- ✓ *National Vision Towards Sustainable Management: Zero Waste*: includes the following guiding principles: Sustainable Development; Circular Economy; Commitment to Corruption and Transparency in Public Management; Attend to Vulnerable Populations Including Social Justice; Reduce Risk and Impacts in Health and the Environment; Social Welfare and Inequality Reduction.

Following these reforms, Mexico's productivity growth has recently picked up in sectors that have benefitted from the structural reforms, namely: energy (electricity, oil and gas), financial, manufacturing and the telecom sectors.

Reform Opportunities

There are however still significant opportunities for sector reform to take place in Mexico. For secondary raw materials markets to work a series of changes need to take place in the way policy makers view and regulate waste. Without these changes, it remains a complex challenge to drive recycling standards and to give confidence to designers of secondary raw materials. This need was first recognised in 2011 by the EU Resource Efficiency Roadmap. Secondary raw material markets need to provide the same services as those currently operational for primary raw materials. Secondary raw material markets therefore need reforms in:

- ✓ buying and selling materials;
- ✓ price transparency;

There are three sectors in Mexico that present considerable business opportunities to bring the sectors in line with the circular economy initiative which can be aided by EU businesses:

(i) Solid Waste management;
(ii) Wastewater;
(iii) Waste to energy.

Business Opportunities in Solid Waste Management

Key Message

There are 1,643 open dump sites in Mexico, however, only 25% of that waste is available for valorisation. Therefore, there is a need for technology implementation specifically in management, collection, sorting, and recycling. This presents a significant market for European companies, specifically within the municipal waste equipment market. Mexico in 2009 had a waste equipment market of 806 million Euros, in 2019 this is expected to be around 1300 million Euros, which is then expected to grow at 6% to 2025.

Business Opportunities in Solid Waste

- ✓ There is a need for information generation and collection of municipal solid waste as it suffers from difficulties in integrating data between national and local levels, as well as between countries; this is due to the lack of harmonization of waste generation and management indicators
- ✓ There exists an opportunity for introducing sorting lines in Mexico where the materials are identified by using automated systems which sort and separate the waste then store and condition it for recycling or valorisation
- ✓ E-waste is now the fastest-growing waste stream in Mexico representing 2.52kg/hab/year, this is a waste stream that is currently not well managed in Mexico.
- ✓ Approximately one third of the total food produced for human consumption –equivalent to 1.3 billion tonnes– is lost or wasted annually, this presents an opportunity to improve food waste management in Mexico.
- ✓ The volume of Construction and Demolition waste is increasing and reached 6.5 million tones anually in Mexico.
- ✓ In Mexico, 5% of all tyres are recycled, 2% are used for energy generation, 2% are disposed in authorized collection centres and the remaining 91% are abandoned or used without control.

Technology trends and opportunities

- ✓ *Management*: New technologies are required for Integrated Waste Management Data Systems
- ✓ *Storage*: There is a need for special containers for automated load; Bins hidden in street furniture; Smart containers and Eco-points
- ✓ *Handling* technologies required: Shredders, crushers, chippers; pulpers; pelleting and briquetting including high compaction balers
- ✓ *Collection*: There is a need for data systems for garbage trucks with automated front, rear and side loading systems; mini rear loaders and multi-compartment vehicles
- ✓ *Sorting and recovery*: Technologies for optical multiplexer sorting systems; sorting systems by density; magnetic separation systems; trommels and screens and Conveyors are required.
- ✓ *Plastic Waste needs*: Mechanical recycling lines; Chemical recycling systems; Up-cycling technologies
- ✓ ***Construction and Demolish waste:*** Integrated recycling lines and equipment: Crushers, Screens and stackers
- ✓ ***Economic Waste:*** Integrated e-waste management from collection, process and recycling schemes
- ✓ *Tyre waste*: Opportunity for upcycling to produce asphalt paviment, running tracks and urban furniture.

Business Opportunities in Wastewater Treatment

Key Message:

Increased water stress coupled with antiquated urban wastewater systems and Mexico's international commitments presents a significant opportunity for EU companies. Furthermore industrial wastewater treatment for reuse with nutrient recovery is an untapped market in Mexico. The wastewater market in Mexico has shifted to the upgrading of plants that are currently not in operation, which will require private sector involvement. Most of these opportunities will materialise as service contracts resulting in capex opportunities of around 2 billion € in the utilities sector and around 600 million € in the industrial wastewater treatment sector.

Business Opportunities in Wastewater

- ✓ EU Companies will increasingly find opportunities in the growing industrial wastewater sector. Contracts here have a lower value than in the municipal sector but there is a higher frequency of projects. Specifically, specialised SMEs could find value in this sector.
- ✓ Technologies in the industrial wastewater treatment sector will focus on Membrane Bioreactors and technologies for material recovery as Mexico looks to upgrade antiquated plants.
- ✓ The highest potential for implementation of new technologies is found in tertiary treatment processes. This also includes technologies related to nutrient recovery and energy generation.
- ✓ It is expected that wastewater networks will also be a major focus of investment in the future in order to connect communities to existing wastewater treatment plants
- ✓ National planning coupled with international commitments sets an objective to treat all the wastewater by the year 2030. This ambitious objective will result in an increase in the number of projects in this sector and result in related market opportunities
- ✓ The situation of the wastewater sector in recent years has shown some uncertainty in the development of regulations due to social and political pressure. This point needs to be considered when establishing market strategies that must adapt to national regulation.

Business Opportunities in Waste to Energy

Key Message

The waste to energy sector can be considered virgin territory in Mexico, a country where successful, large scale projects are scarce. Mexico will require 95 billion Euro investments over the next 15 years for power-related infrastructure projects. Of this, 81% would be required for generation projects, 11% for transmission projects, and 8% for distribution projects. The Secretaria de Energía (SENER) estimates that about 137 generation units, totalling 15,814 MW (nearly 16 GW), will need to be retired. This means Mexico will need to add 56 GW of new capacity between now and 2031. The target is to make clean energy account for 38.2% of its total power generation by 2031.

Business Opportunities in Waste to Energy

- ✓ FIBRAs (Real Estate Investment Funds), has changed the Industrial Park development trend by offering retrofitting opportunities with localized portfolios of Waste to Energy solutions.
- ✓ Wastewater: The anaerobic treatment of wastewater in Mexico has proven to be successful in both municipal and industrial sectors, and this area is the most mature of all biogas subsectors in Mexico, however significant opportunity still abounds by bringing other wastewater treatment plants in line with this trend.
- ✓ Combustion of dehydrated residual sludge: Currently there are no cases in Mexico where the combustion potential of this residue is utilized. Landfills are still a preferred method of disposal for dehydrated residual sludge, mainly due to the lack of experienced service providers rather than other market barriers.
- ✓ Agricultural (Meat and Dairy farms): biogas plants are seen to be profitable if they possess good design, quality equipment, and good practices in operations are implemented. Key technological and operational improvements can make these projects financially attractive for farmers with access to financing and government subsidies.
- ✓ The Food and Beverage Industry: In collaboration with the Danish Energy Agency, SENER is expected to release a complete biogas potential characterization. This will make it easier to perform preliminary feasibility studies of biogas projects that deal with the digestion or co-digestion of these substrates that are abundantly found in Mexico.

- ✓ **Organic Fractions**: Still requires validation projects that necessitates the involvement of international consultants with successful track records. Mexico has 36 municipalities which have a population of over 500,000 in which large scale food waste biogas plants can be implemented (INEGI).
- ✓ **Municipal Landfill**: In 2015, there were only 8 landfills with a total installed capacity of 34MW that was generated from biogas. This means that there are at least 252 landfills in which biogas generation projects can be implemented.

Conclusions

There are three main sectors in Mexico that present significant opportunities in bringing the sectors towards the circular economy concept, these are: Solid Waste Management; Wastewater Treatment and Waste to Energy. The solid waste management sector has two main areas that present opportunities: Municipal Solid Waste and Special Handling Waste. It is estimated that bringing the Mexican solid waste market to a more circular economy has a potential worth of 1,172 million Euros per year. In terms of the Special Handling Waste, for instance the electronic waste represents a potential of 1 billion Euro market value that could be recovered each year through introducing circular solutions. Furthermore, the increasing building materials recycling and reuse activities will require an investment of up to 180 million Euro per year to scale up the number of CDW recovery plants in the main 10 cities in Mexico.

Keeping pace with the significant consumption and production in Mexico, the water sector demonstrates significant water stress mainly related to climate, demography and industrial volume use. A lower level of water stress is a good indicator to show improved water management, wastewater treatment and reuse. The wastewater treatment sector has a potential market opportunity size for circular solutions of around 1,644 million Euro for CAPEX related investment in wastewater treatment. Most of this increase is related to wastewater networks, whereas an increase in sludge management is lower in absolute values and capex is approximately constant for wastewater treatment plants. Operational expenses also show a steady increasing trend with the opportunities more significant for industrial uses (20.6%, from 1,035.3€ million to 1,249.2€ million) than for wastewater utilities (8.3%, from 731.8€ million to 792.3€ million).

Indeed, it is within the wastewater treatment sector that significant opportunities arise in waste to energy production for both biogas and combustion technologies. However, to date, there is no record of a WWTP that is transferring its dried sludge to industrial facilities to be used in co-combustion processes. Furthermore, in the waste to energy sector, biodiesel infrastructure investment opportunities are estimated at 845 Million Euro from years 2018 to 2036.

2. INTRODUCTION

For many years the global economic model has been based on a linear model of production. This model can be summarised as the: take-make-use-dispose model, where resources are converted to products that are destroyed at the end of their life. However, the linear model is also characterised by driving down natural resources, increasing the emissions of greenhouse gases, generating vast amounts of plastic waste which all result in significant environment damage. It is precisely this economic model that is no longer compatible with economic advancement. The circular economy model, on the other hand, converts waste into new resources that implements a sustainable system of creation - use - reuse. This model results in a paradigm shift that is encouraging companies to completely reconsider their production strategies and processes while obtaining new markets.

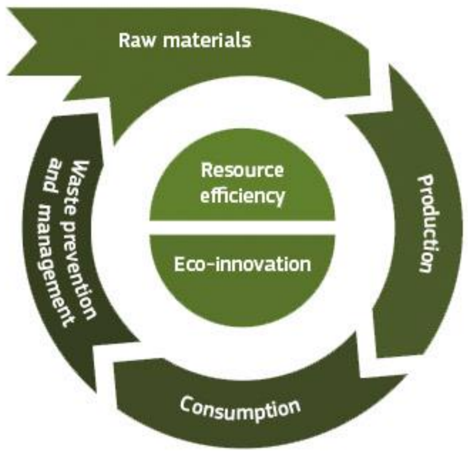
The first industrial revolution was built around low-cost primary raw materials and the innovation and skills to exploit them through mechanisation in the late 18th century. The early 20th century saw industrialising countries move through the second industrial revolution when they built their industrial base and wealth through mass production using those raw materials. Such countries have maintained that position with falling raw material prices and increases in labour productivity for nearly a hundred years. During that time, they have built an economy with massive raw material supplies embedded into the infrastructure and the goods and commodities their communities use. The same model has survived as OECD countries have offshored manufacturing (largely driven by lower labour and manufacturing costs) to the new economies such as China, India, Brazil, Vietnam and Bangladesh who are all growing strongly. As a consequence, the global community has seen a growing scramble for the globe's resources, which is not sustainable.

It was in 1972 that a report from the Club of Rome[2] stressed the idea of the limits to the continuous increase of material wellbeing and expressed the limits to the extent with which humans can exhaust the natural environment. Within this context, the need emerged to investigate a new economic model to face the challenges of the availability of the resources coupled with environmental protection, there within came the proposal of an innovative economic model: Circular Economy (CE). The current understanding of the Circular Economy and its practical applications to economic systems evolved to incorporate different features and contributions from a variety of concepts sharing the idea of closed loops. Some of the relevant theoretical influences are cradle-to-cradle, laws of ecology, looped and performance economy, regenerative design, industrial ecology, biomimicry and blue economy (Ghisellini, Cialani and Ulgiati, 2016). The concept was proposed as an alternative to the negative effects caused by the linear economy model, in which the (re)design of the production systems at a variety of levels coupled with value retention in the production chains as well as during the life cycle of the resources, materials and products is key. This often leads to new and intensely connected recycling and reuse patterns, mostly of a cyclical nature and leading to value creation that is mutually dependent[3]

[2] The Club of Rome is an organisation of individuals who share a common concern for the future of humanity and strive to make a difference. The members are notable scientists, economists, businessmen and businesswomen, high level civil servants and former heads of state from around the world. The mission is to promote understanding of the global challenges facing humanity and to propose solutions through scientific analysis, communication and advocacy.

[3]European Commission (2018), Organising for the circular economy (2018).

Keeping these concepts in mind, manufacturers now design products that consider the entire lifecycle and not just relinquish responsibility at the point of sale. This concept of cradle-to-cradle means that designers should create longer lasting products, reuse parts and use less materials. Therefore, the circular economy is aimed at maximizing reusability of products, parts and resources and to minimize value destruction.[4] This model incorporates a regenerative system, with the aim to retain as much value as possible of the product parts and materials.[5]



A circular economy is 'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised' (European Commission 2018)[1]

Figure 1. The conceptual diagram of the Circular Economy as proposed by the European Commission[6]

The Ellen MacArthur Foundation[7] affirms that circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital. It is based on three principles:

i. To design out waste and pollution
ii. To keep products and materials in use for as long as possible
iii. To regenerate natural systems. (Ellen MacArthur Foundation (2012)

With the current advances in digital technology there is the influence to support the transition to a circular economy by radically increasing virtualisation, de-materialization, transparency, and feedback-driven intelligence.

The global market trends coupled with the specific market trends in Mexico give us an overview of which sectors have been the driving force in the global economy over recent years and prediction of where the future market opportunities exist.

Therefore, to generate a paradigm, shift from centuries old linear economic models to future circular models requires an open and innovative enabling environment. In this sense, this report looks at the current policies and legislation that is driving the market towards a circular economy approach. Section 1.9 of this report brings a culmination of the previous sections to feature success stories from Mexico or internationally where the descriptions and key success factors have been detailed.

[4]European Commission (2018), Organising for the circular economy (2018).
[5]European Commission (2018), Organising for the circular economy (2018).
[6] http://ec.europa.eu/environment/green-growth/tools-instruments/index_en.htm
[7] https://www.ellenmacarthurfoundation.org

Within the circular economy approach and framework, section 2 of this report takes a deep dive into three main sectors where the greatest potential exists to foster a paradigm shift into the circular economy model that will bring positive economic and environmental impacts. These three sectors are:

(iv) Solid Waste management;
(v) Wastewater;
(vi) Waste to energy.

Finally, in chapter 4 financial instruments that are currently available both internationally and nationally are detailed to aid both European and Mexican businesses to identify the best financing opportunities to work together to bring about this paradigm shift.

2.1. TRENDS IN CIRCULAR ECONOMY

According to the International Solid Waste Association report, the annual material cost saving opportunity at EU level for a "transition scenario" is €300 to 340 billion per annum and for an "advanced scenario" €460 – 590 billion or a recurring 3-3.9% of 2010 EU GDP, for the materials used in the circular economy processes[8]. The UN Global Compact study[9] on the views of CEO's on Sustainability in the Mining and Metals sector shows that the concept of the circular economy has taken hold quickly among CEOs focused on innovation and the potential of new business models. With a potential €1 trillion opportunity in transitioning to the circular economy, companies are recognising that preservation makes as much economic sense as it does environmental. It is thus evident that transforming to a circular economy is economically beneficial, however trends within different initiatives give us an idea of where the best economic opportunities lie within the circular economy paradigm shift.

2.1.1. TRENDS IN INITIATIVES

On 4 March 2019, the European Commission adopted a comprehensive report on the implementation of the Circular Economy Action Plan[10]. The report presents the main achievements under the Action Plan and sketches out future challenges to shaping the EU economy and paving the way towards a climate-neutral, circular economy where pressure on natural and freshwater resources as well as ecosystems is minimised.

The Action Plan establishes a concrete programme of action, with measures covering the whole product cycle: from production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste. The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and to bring benefits for both the environment and the economy.

Further to the Action Plan, there are European legislations and strategies such as the revised legislative framework on waste that entered into force in July 2018. The framework sets clear targets for the reduction of waste and establishes an ambitious long-term path for waste management and recycling. Additionally, the Europe-wide EU Strategy for Plastics in the Circular Economy includes the way plastics and plastic products are designed, produced, used and recycled. The EU has set the target that by 2030, all plastic packaging should be recyclable. To achieve this ambitious aim, the strategy foresees actions to improve the economics and quality of plastic recycling; to curb plastic waste and littering and to drive

[8] https://www.iswa.org/fileadmin/galleries/Task_Forces/Task_Force_Report_1_02.pdf
[9] https://www.accenture.com/us-en/insight-un-global-compact-ceo-study
[10] http://ec.europa.eu/environment/circular-economy/index_en.htm

investments and innovation. To reduce plastics into the environment, the Commission has also adopted a new proposal on Port Reception Facilities, to tackle sea-based marine litter and published a report on the impact for the use of oxo-degradable plastic, including oxo-degradable plastic carrier bags, on the environment.

Moreover, the EU put forward the EU Strategy for Plastics in the Circular Economy to reduce the impact of certain plastic products on the environment. The Strategy proposes different measures for specific items made of single use plastics considering consumer behaviour as well as consumer needs and opportunities for businesses. When alternatives are clearly available – both single use and multi-use plastic bags – market restrictions are then proposed. Other measures include appropriate labelling, awareness raising, voluntary actions, and the establishment of Extended Producer Responsibility schemes that would also cover the costs for the clean-up of litter.

In terms of raw materials, the European Commission has produced a vision on the use of Critical Raw Materials (CRMs) and the circular economy that highlights the potential to make use of the 27 critical materials in the EU economy more circular. This vision report provides key data sources, suggests several best practices and identifies options for further action, to ensure a coherent and effective EU approach to CRMs in the context of the transition to a circular economy.

When considering the circularity of the water cycle, the European Commission has put forward a proposal for a Regulation on minimum requirements for water reuse - the proposal is setting the minimum requirement to boost the efficient, safe and cost-effective reuse of water for irrigation -and thus delivering the Circular Economy Action Plan.

In monitoring the achievement of these circular economy initiatives at European level, the European Commission in 2018 produced the Monitoring Framework on progress towards a circular economy at EU and national level. It is composed of a set of ten key indicators which cover each phase – i.e. production, consumption, waste management and secondary raw materials – as well as economic aspects – investments and jobs - and innovation. They have also produced an interactive website following the progress of these initiatives: https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework.

2.1.2. TRENDS IN TECHNOLOGY AND BUSINESS MODELS

The above-mentioned trends to change to a circular economy, are affected by the rapid pace of technological innovation. The Report on the Next Manufacturing Revolution[11] considers that the OECD countries are entering the next major manufacturing revolution in what they call "Circular Resource Flows". According to the World Economic Forum[12] supply chains are the key unit of implementation that will drive the technological trends in the circular economy. Analysing the most advanced business cases confirms that a supply chain management approach that balances the forward and reverse loops and ensures uniform materials quality is critical to maximising resource productivity globally. For instance, advanced tracking and treatment technologies is a key innovation point that can boost the efficiency of both forward and reverse logistics.

[11] http://www.nextmanufacturingrevolution.org/wp-content/uploads/2013/09/Next-Manufacturing-Revolution-full-report.pdf
[12] http://reports.weforum.org/toward-the-circular-economy-accelerating-the-scale-up-across-global-supply-chains/executive-summary/

A 2018 report by The Warren Centre on *The Circular Economy: Global Trends and Future Challenges*[13] identifies current global trends towards a circular economy for industrial systems, products and consumers. The report identified three (3) main technological trends in circular economy: (i) Partnerships (covered in section 1.1.2), (ii) Industrial design reform and (iii) New Business Models.

Industrial design reform

Currently, industrial design is characterised by planned obsolescence and bespoke and unique parts that make replacement difficult. Extending product lives will result in a decline in revenue for suppliers. However, manufacturers could learn from other industries such as music, television or even private transport that are moving towards a subscription-based service. Subscription based services provide a better business model to apply the circular economy processes and concepts. For a product designed with recycled materials to be financially viable, a steady supply of that recycled material is required. The kind of recycling infrastructure that would provide industrial volumes of secondary raw material are rare throughout the world and require significant technical development and supportive legislative advances. For continued benefits in the long term, circular economy concepts need to be taught in industrial design courses and to be taken up from the very start of the product design.[14]

Business Models

Increasingly business models for consumer products have been shifting from a product-based system to a product service system (PSS). A product-based system involves firms selling discrete goods to the consumer, incentivising manufacturers and marketers to create more products to sell to more buyers to make more profit. This has been the traditional business model for consumer products and has been entrenched by technological constraints, force of habit and the need for individuals to have control and ownership over objects. Alternatively, in a PSS, a firm does not sell a product but rather a fulfilment of a need, and the product is merely a channel for satisfying consumer needs. This is seen in ridesharing services like: Uber (Global), GoGet[15] (Australia) OBike[16] (Singapore), and even for shared office spaces (e.g. SC Trade Centre[17] in Spain). These business models prioritise access over ownership and takes advantage of the idle capacity of these goods.

[13] https://thewarrencentre.org.au/publications/circular-economy/
[14] The Warren Centre (2019), *The circular economy* (2019)
[15] https://www.goget.com.au
[16] https://www.o.bike
[17] http://sctradecenter.es/web/

2.2. COUNTRY AND CONTEXT OVERVIEW

The current study brings a focus on the market opportunities in Mexico in relation to Circular Economy solutions in the solid waste, wastewater and waste to energy sectors. The shift towards a circular economic model comes at a good time for the Mexican economy as a recent economic survey by the OECD in 2017, showed that the Mexican economy is seen as resilient with recent indicators suggesting that there is further growth ahead[18]. Given that the external economic environment is turbulent, with the global economy remaining in a low-growth environment coupled with weak global trade and investment, innovation in these 3 major sectors in Mexico will be vital to secure future economic, social and environmental sustainability. Specific challenges to the Mexican economy include collapsing oil prices, which reduced government receipts and led to cutbacks in energy sector investments, as well as the sharply depreciating Mexican peso following market expectations of US Federal Reserve tightening and rising global policy uncertainty. However, despite these shocks, performance is good, supported by domestic demand. The structural reforms related to waste and water are supporting economic growth.

The OECD further elaborates that output growth in Mexico is projected to accelerate modestly to 2.1 and 2.3 % in 2018 and 2019, respectively, and to then gradually converge to just under 3% over the medium term as uncertainty subsides and the economy reaps the full benefits of the implemented structural reforms. Inflation is expected to converge toward the Bank of Mexico's 3% target in the second half of 2019. The main risks to the outlook include weaker-than-projected global growth, renewed volatility in global financial markets, and global trade-related uncertainty.

Private consumption continued to be the main driver of growth on the demand side, including on the back of real wage growth turning positive in the first half of 2018. Oil production, which had declined to 1.9 million barrels per day (bpd) by the end-2017, from 2.6 million bpd five years earlier, had shown no sign of a trend reversal by mid-2018, as large investments in extraction are progressing slowly. With the elections behind Mexico, as well as the trilateral US-Mexico-Canada Agreement (USMCA) on trade, these past uncertainty factors should fade, helping to support a further, albeit moderate, rebound in investment. Weakness in the currency and asset markets in advance of the July Presidential election had been more than reversed by early August, with the incoming administration's economic team signalling its commitment to prudent fiscal and monetary policies implying continued adherence to the Fiscal Responsibility framework as well as the principle of Central Bank independence.

2.3. SOCIO-ECONOMIC CONTEXT

According to the OECDs *How is Life in Mexico*[19], relative to other OECD countries, Mexico has a mixed performance across the different well-being dimensions. The employment rate in Mexico of 61% in 2017, is below the OECD average (67%), but the long-term unemployment rate was close to zero, one of the lowest levels in the OECD countries. Housing conditions are below the OECD average for all three indicators, and the average life expectancy at birth (75 years in 2015) is 5 years below the OECD average. Mexico has the highest homicide rate, with 18 homicides per 100 000 people in 2016. Mexico also ranks low in terms of education and skills but is in the top tier of OECD countries in terms of life satisfaction

However, following the general elections in 2018 a new political landscape is shaping up in Mexico. The new President, López Obrador, has promised to reduce corruption and crime, and boost social spending

[18] https://www.oecd.org/eco/surveys/Mexico-2017-OECD-economic-survey-overview.pdf
[19] https://www.oecd.org/statistics/Better-Life-Initiative-country-note-Mexico.pdf

and public investment, while maintaining fiscal cautiousness. The incoming administration will inherit an economy with very strong fundamentals and policy frameworks that has exhibited resilience in the face of a complex external environment. Nevertheless, since the crisis of 2009, Mexico has observed a process of deceleration of imports. Due to its geographical location and the historical commercial ties, international purchases with USA (46.8%) and Canada (2.1%) amount to 48.9% of the total imports to Mexico. This is far greater than the countries of the *Latin American Integration Association* (ALADI) and from Central America together (see Figure 2). Trade with the main Asian countries represents 28.2% of other country imports, surpassing the imports of the European Union and the *European Free Trade Association* (EFTA).

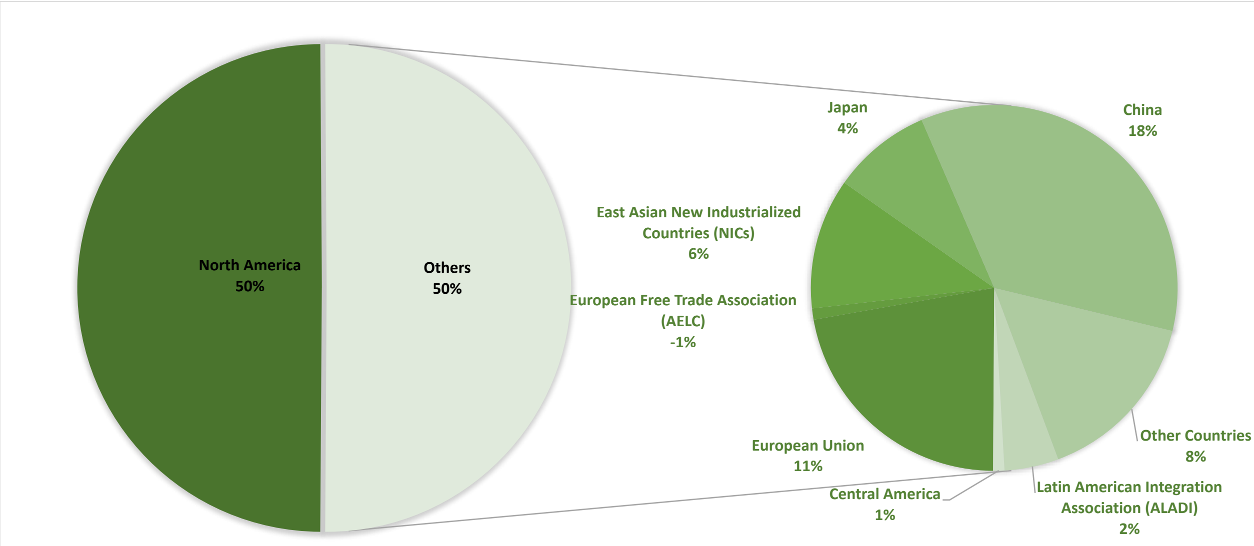


Figure 2. Mexico's trading partners (authors own elaboration, data from OECD)

Regarding the composition of these imports, the share of manufacturing goods represents more than ninety percent of the country's purchases abroad. Of all the imports, 69.6% of the manufactured goods have an international division of production plants located in several Mexican states.

However, inequalities continue to persist across states and sectors, emphasising the divergence of a modern Mexico - highly productive, competing globally - and a traditional Mexico – less productive, with small-scale informal firms, mostly located in the South with significant gender balance issues.

Against this background, Mexico, under the new administration, needs to develop reforms to focus principally on the following points.:

- How to ensure that resilient growth continues, reducing oil dependence, preparing for vulnerabilities and exogenous shocks, and supporting more social spending.
- How to reduce inequalities with policies to better fight poverty, promote women's opportunities, and foster responsible business practices.
- How to ensure inclusive productivity growth by reforming key sectors of the economy, climbing global value chains, lowering regulatory barriers, tackling informality, and reducing corruption and moving the Mexican economy away from linear to more circular economic models.

There has already been some short-term gain demonstrated through sector reforms, especially on productivity growth. The reforms are looking to fit with the long-term Sustainable Development Goals (SDGs) to be achieved by 2030. Particular focus for Mexico is on eradicating extreme poverty (SDG 1), raising female participation (SDG 5), improving access to water and sanitation (SDG 6), improving affordable and clean energy (SDG 7), improving economic opportunities (SDG 8), reducing income inequality (SDG 10), and encouraging more responsible business practices (SDG 12).

2.4. OVERVIEW OF THE CIRCULAR ECONOMY IN MEXICO

Mexico in 2011 was stated as being far away from having any semblance of a circular economy, and it was thought, at the time, that the effort in many sectors of Mexican society to transform into a circular economy would not be forthcoming (Gottesfeld and Durand, 2011). It was mentioned in 2011 that this transition to a circular economy would require changes in recycling and reuse of waste; changes in production and consumption, and in the institutional systems surrounding production and consumption, such as in legislation, education, knowledge transfer, environmental awareness and entrepreneurial cultures.

The production of waste in Mexico is particularly worrisome. It generates more than 44 million tons of waste per year and this number is expected to reach 65 million by the year 2030[20]. Given that a linear economic model in this sense would be wholly unsustainable, the Mexican government put forward a regulatory framework and public policy instruments, such as the National Programs for the Prevention and Integral Management of Waste, which seeks to promote the valorisation of waste and to minimise the impact on the environment and particularly to human health. Similarly, Mexico has international obligations through its signed corresponding international agreements to manage waste and chemical substances as a global priority, thus complementing the integral management at the national level.

However, it was not until January of this year (2019) that Mexico put forward a vision document *National Vision Towards Sustainable Management: Zero Waste.* Within this document a roadmap was laid down on how Mexico could move towards a circular economy, it specifies the formulation and implementation of public policies, as well as the execution of instruments, programs and plans, to strengthen the management of waste in the country.

This document puts forward 6 guiding principles:

1. Sustainable Development.

To consider the integrity of the development of the country, with economic, social and environmental aspects.

2. Circular Economy.

To establish the grounding and to develop the mechanisms and instruments to implement a circular economy approach that strengthens the sustainable management of materials, with a zero-waste vision.

3. Commitment to Corruption and Transparency in Public Management.

To prevent and avoid irregularities in the provision and collection of waste services.

4. Attend to Vulnerable Populations Including Social Justice.

[20] https://www.gob.mx/cms/uploads/attachment/file/435917/Vision_Nacional_Cero_Residuos_6_FEB_2019.pdf

To provide training and services to isolated populations with few inhabitants. Formation of cooperatives and work groups to collaborate in the collection, accumulation and management of waste.

5. Reduce Risk and Impacts in Health and the Environment.

To avoid the proliferation of diseases and harmful effects on health due to the inadequate management of waste, as well as the risk and impacts on the environment.

6. Social Welfare and Inequality Reduction.

To expand service coverage and serve communities under 10 thousand inhabitants. Establish coordination and follow-up mechanisms to achieve harmonization and articulation with programs and policies related to gender equality.

Following these guiding principles, the document has put forward a roadmap towards zero waste where the integral management of waste includes hazardous waste, urban solid waste, wastewater and special waste. The scope of this document is primarily focused on solid waste, considering the biggest issue facing Mexico in terms of waste is the size and number of open dump sites and sanitary landfills. Furthermore, solid waste has given rise to the formation of contaminated sites or open dumpsites where there is proliferation of informality, and space for irregularities in waste management to exist which are significant barriers to implement a circular economy model. To reduce the risk of exposure to waste in landfills, this document directs the action to the flows and processes of classification, collection, transport, transfer, reuse, recycling, storage and recovery into new valorised materials and energy. The vision is to bring forward these concepts to allow for the gradual reduction of solid waste and to reduce and finally close solid waste landfill sites.

The Roadmap includes the following 6 main goals:

1. A thorough diagnosis of the infrastructure, capacity, market and management of waste in the country.
2. The closure of final disposal destinations (open dumps and landfills) that do not comply with the regulations.
3. To design the platform of technical assistance and finance for the management of waste in all Mexican states.
4. The creation, adoption and operation of models for the sustainable management of waste.
5. To transform open dumps into material banks and to create markets for recycled raw materials, promoting the remanufacturing and recycling industry.
6. To eliminate food waste and to take advantage of the organic and energetic potential of the waste.

The response from the public sector in providing a vision for a circular economy in Mexico has in many regards already been met by the private sector as they see a market niche and an economic gain in moving towards a circular economy. Currently, Veolia - a world leading European company in water, waste and energy management – has developed innovative processes to create access, preserve and reuse natural resources and thus respond to emerging needs globally. It has various projects based on the circular economy, in Europe, specifically in Brussels, where bioplastics are produced from wastewater; at the regional level, in Chile, they recover the copper from the sedimentation tanks.

Another example of circular solutions that are using private sector initiatives is the case of the largest green roof in Latin America, located in Mexico City, with an area of 2,270 square meters and more than 125 different species of vegetation. The budget for this initiative was 9.8 million pesos (0.2 million Euros) with the instillation following the guidelines and implementing Swiss technology based on the usage of polymers and geotextiles. The polymer undergoes a thermofusion process with heat, it is attached to the floor and sealed completely. This plastic is accompanied by geotextiles and geodren, a technique that stores water long enough, so the plants and vegetation can take the essential nutrients.

Figure 3. The largest Green Roof in Latin America, on the INFONAVIT National Workers' Housing Fund Institute (photo credit: The Mazatlan post)

2.5. PRODUCTION AND CONSUMPTION PATTERNS IN MEXICO

The production and consumption patterns that govern the globe, present serious contradictions and challenges in the logic of sustainable development and specifically within the framework of the so-called "green economy". To achieve a paradigm shift, the 2030 Agenda for Sustainable Development[21] proposes in its Goal 12 to promote the efficient use of resources and energy; build infrastructures that do not harm the environment; improve access to basic services; and the creation of well-paid ecological jobs with good working conditions. Clearly the elaboration of the Sustainable Development Goals represents an advance, but where economic growth is governed by the consumption of fossil fuels make the viability of achieving Goal 12 difficult.

Mexico's performance on the progress of SDG Goal 12 on ensuring sustainable consumption and production patterns is estimated according to data from the SDG Index and Dashboards Report 2017 (Sachs *et al.*, 2017). Table 1 shows Mexico's position in the global ranking of sustainable production and consumption which has a ranking of 74,2 meaning that Mexico is 74,2% of the way to completing all indicators within the SDG12. **¡Error! No se encuentra el origen de la referencia.**

Table 1. Indicators of Mexico's achievement to SDG 12 on Sustainable Production and Consumption (modified from SDG index)

	E-waste	8.2 kg/capita
	Wastewater treated	45.6 %
	Production-based SO2 emissions	16 kg/capita
	Net imported SO2 emissions	-1.3 kg/capita
	Nitrogen production footprint	27.8 kg/capita
	Net imported emissions of reactive nitrogen	34.4 kg/capita

[21] https://www.un.org/sustainabledevelopment/development-agenda/

12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Non-recycled municipal solid waste	1.3 kg/person/day

As can be noted in table 1, Mexico has made important advances to promote sustainable consumption and production, however progress in terms of transforming the systems into circular processes has been very limited. For instance, Mexico is the country with the fifth highest use of cardboard and paper secondary fibres. In 2017, only 0.77% of the federal budget for administrative materials and official documents and articles was spent on sustainable purchases. Furthermore, only approximately 9.6% of the 44 million tons of solid waste generated in Mexico's cities is recycled each year (SEMARNAT, 2010), where 70% of that urban solid waste ends up in landfills (INEGI, 2016). With regards to food waste it is estimated that 34.5% of the country's total food production is wasted (over 20 million pounds of foodstuffs). This wasted food would be enough to feed 7.4 million Mexicans (World Bank, 2017).

However, in terms of policy and legislation, Mexico is moving to change these unsustainable production and consumption patterns. For instance, Mexico has legislation on the comprehensive management of solid waste, solid waste management plans and decentralized Comprehensive Urban Solid Waste Management Agencies. The National Chemical Substances Profile shows the country's infrastructure for the management of waste and other substances. The National Management Plan for Vehicles at the End of their Useful Life and the analogous television collection program contribute to the proper management of dangerous substances. There are also legislative reforms on public purchases that include sustainability criteria, such as (1) modifications to Public Sector Acquisitions, on equality between women and men, which incorporates gender equality provisions; and (2) the Energy Transition Law, which regulates sustainable electricity use.

Furthermore, since November 2012, Mexico has a National Strategy for Sustainable Production and Consumption. This strategy establishes the bases for stakeholders to consolidate integration actions at a vertical and transversal level, to adopt patterns of production and consumption that are attached to sustainability with a focus directed towards social benefit (SEMARNAT, 2013). The Strategy highlights the importance of aligning sectoral policies towards a global dimension of sustainable development through the coordination of efforts of the public and private sectors to create and implement policies that catalyse the development of projects and that encourage the adoption of sustainable practices. The Strategy guiding principles are intrinsic to the application of measures in order to serve as a guide in the actions of social actors and decision makers, such as: quality of life; access to the information; citizen participation; the gender perspective; the life cycle perspective of the products; the culture of sustainability; the common but differentiated responsibility; the precautionary principle; inter and intra-governmental coordination; and the reduction, reuse and recycling. All these aspects of the National Strategy for Sustainable Production and Consumption go hand in hand with the concepts of a circular economy.

However, the achievement of the National Strategy together with SDG 12 cannot be done in isolation and needs to be considered in a sustainable manner. Looking at the sector sustainably indicates how consumption and production are related. The production of an object requires the extraction of the natural resources (raw material) with which it is going to be produced. Often it requires water, energy and fuels that are combined with the object and the waste that is discarded. Its industrial development generates emissions of greenhouse gases that generate global warming, and the final destination of the product are sent to landfill. The complexity to achieve sustainable consumption and production development lies in the interdependence of its causes and the trade-offs and synergies that occur between the social environmental and economic systems. To align production and consumption in an efficient approach is to do so through the concepts of a circular economy, which can be seen in three basic parts: production, consumption and the surrounding support system. Each of these parts has its own elements and characteristics, and the interaction of them determines the chances for Mexico to transform its consumption and production patterns into a circular economy and its achievement of SDG 12.

2.6. MARKET TRENDS

According to a report by JP Morgan[22], growth in the global economy is set to slow down slightly in 2019 with expectations of 2.9% growth. The U.S. economy is set to post a moderate 1.8% growth in 2019, as fiscal, monetary and trade policies start to constrict. Recent disruptions in the euro area industry are expected to fade and the region is forecast to grow to 1.7%, offsetting some of the moderation in U.S. growth. China is facing a considerable challenge in sustaining growth at around 6% as it deals with internal imbalances and external struggle. However, after a challenging 2018 many Emerging Market economies are forecast to grow strongly in the second quarter of 2019. Latin America is the one region with modestly faster activity forecast in 2019, as China is heavily contributing to the overall Emerging Market slowdown.

Within the Emerging Market, Mexico is now the world's 11th largest economy (in terms of GDP measured at purchasing power parity). The country has gone through tremendous structural changes over the past three decades. From an oil-dependent economy up to the early 1990s to a booming manufacturing centre in the aftermath of NAFTA in the mid-1990s, Mexico is now increasingly becoming an international trade hub. Given that the economy has been relatively stable over the past decades, with an average growth of 2.6% in the past 10 years[23], a report on the *World in 2050 the BRICs and beyond*, indicates that Mexico is indeed projected to become the world's 8th largest economy in 2050, in front of Russia, the UK and France[24].

Mexico's geographical location favours economic development, as it is centrally located in-between most of the world's economic centres. The dependency on the American economy, however, makes the Mexican economy vulnerable to changes in political relationships between the two countries, as well as in fluctuations in the American economy. A diversification of the economic relationships of Mexico with other parts of the world is therefore needed to ensure a sustained economic growth in the coming decades.

Mexico is still predominantly a country of manufacturers, complemented with tourism, mining, agriculture, real estate and construction, while the financial and service sectors are gradually gaining importance in the national economy (Dielman, Hans, Martínez-Rodríguez, 2018). Industrial production and manufacturing predominantly hail from the famous Mexican *maquiladoras*. The greatest

[22] https://www.jpmorgan.com/global/research/global-market-outlook-2019
[23] http://www.oecd.org/dev/americas/LEO-2019-Chapter-1.pdf
[24] https://espas.secure.europarl.europa.eu/orbis/sites/default/files/generated/document/en/World%20in%202050.pdf

concentration of these maquiladoras is found in the northern part of the country, with proximity to the US border.

The continued economic potential in Mexico is however hindered by important challenges in recent years, such as high levels of poverty, extensive informality, low female participation rates, insufficient educational achievement, financial exclusion, weak rule of law, and persistent levels of corruption and crime. To address these problems, reforms including the *Pacto por México*, has led to notable progress across a range of areas and has put Mexico at the forefront of reformers among OECD countries (OECD, 2015). These ambitious structural reforms coupled with sound macroeconomic policies have ensured the resilience of the highly-open Mexican economy in the face of challenging global conditions.

Following these reforms, Mexico's productivity growth has recently picked up in sectors that have benefitted from the structural reforms, namely: energy (electricity, oil and gas), financial, manufacturing and the telecom sectors. Reforms related to trade openness, foreign direct investment, integration into global value chains, and innovation incentives have also boosted exports, notably within the car and truck industries. This has resulted in the Mexican manufacturing sector producing, as a single nation, a significant part of the world's cars, trucks, computer parts, light vehicles, TVs and mobile phone parts (see Figure 4).

These trends in market growth and increased trade with Mexico is putting strain on the natural resources with Mexico's automotive industry, one of the most rapidly growing water-intensive manufacturing sectors in the country, with double digit growth in each of the last five years. The enforcement of environmental regulations paired with the rapid growth of the industry in the water-scarce north will create a high demand for water supply and wastewater treatment and reuse solutions. There will be a need for demineralised and softened water and the latter metal and hydrocarbon removal, reuse solutions, and the treatment of sludge. The concentration of water-polluting industries in the northern part of Mexico and along the US border mean these states will have higher industrial water treatment demand than other parts of the country. Clients in this sector include Chrysler, Hitachi, Kia, Audi, Nissan, and Mercedes-Benz, among others (Global Water Intelligence, 2016, pp 452).

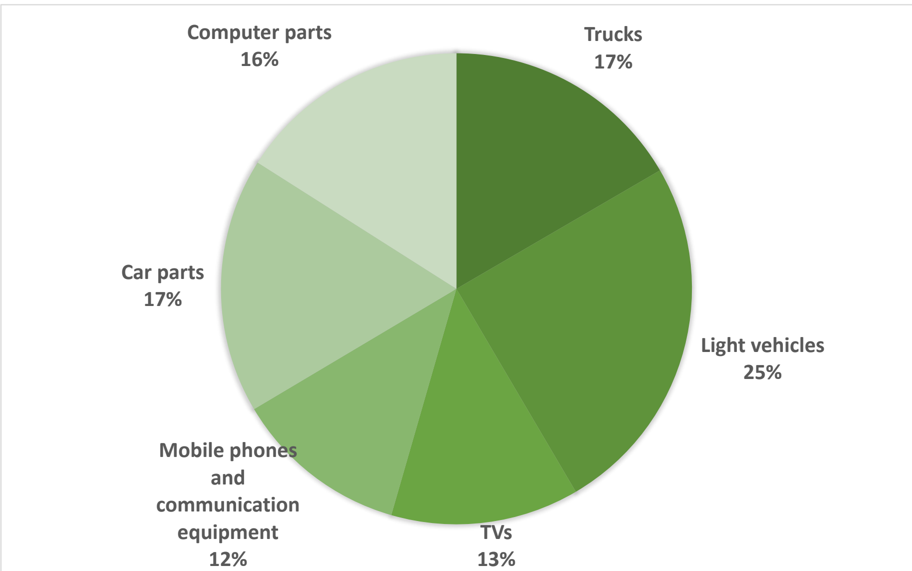


Figure 4. Percentage of Mexico's total manufacturing of the World's total. Authors own elaboration data taken from Pèrez (2015).

Within the food and beverage sector opportunities exist for providers of advanced filtration methods such as reverse osmosis, micro-filtration, ultra-filtration, and UV disinfection, which are used to both purify the ingredient water and treat the wastewater. Clients in this sector include Coca Cola, Pepsi, Alpura, LaLa, and Jose Cuervo, among others (Global Water Intelligence, 2016, pp 471).

In 2014 a new energy reform measure opened up Mexico's oil sector to private and foreign investors, whereas previously only the national oil company, Pemex, had exploration and production rights. One result of the reform is that Pemex can now form joint ventures (JVs) with private and foreign enterprises to invest in and manage critical areas of their operations, including exploration and production, logistics, and refining. Opportunities in upstream oil and gas are found in the treatment of produced water after oil separation and the implementation of enhanced oil recovery (EOR) methods. At the end of 2015 Pemex announced a multi-year $23 billion investment to upgrade existing refineries. Should the announced investment come to fruition, opportunities would be in solutions for cooling water production, boiler and process water and the treatment of hydrocarbon-contaminated wastewater. Advanced technologies such as demineralisation, ultrafiltration, membrane bioreactors, and reverse osmosis will be in demand (Global Water Intelligence, 2016, pp 471).

Within the wastewater market in Mexico the priority has shifted to the upgrading of plants that are currently not in operation (40% of all WWTPs), which will require private sector involvement. Authorities are currently structuring new programmes to bring in private sector expertise to improve the operational, technological, and financial capabilities of utilities. Most of these opportunities will materialise as service contracts (Global Water Intelligence, 2016). The main investment programme which has funded the majority of large WWTPs in Mexico is the Modernisation of Water Operating Organisations Program (PROMAGUA). Targeted towards municipalities of more than 50,000 inhabitants, the aim of PROMAGUA is to incentivise investment partnerships in water supply, sewage, and wastewater treatment projects. Depending on the private sector contribution, the programme grants funds to cover up to 50% of the initial investment for water supply, sanitation, and desalination projects. For projects related to improving the operational efficiency of the utilities, it will fund up to 40% of the investment. The priority will be in building WWTP for communities of less than 50,000 residents and investing in upgrades of out-of-date plants, as well as bringing into operation offline plants (Global Water Intelligence, 2016, pp 451).

Within the solid waste management sector, Mexico is not doing very well. While the country holds the number 2 position overall in the import of environmental technology from the USA, it is ranked only number 13 in imports of solid waste management technology. Waste management technology imported from the USA includes waste handling equipment, biogas capture technologies, sanitary landfill systems and sorting machines. There is however a growing interest in applying environmental technology in all sectors of the Mexican industry, mainly due to more stringent environmental legislation. This creates a demand that is largely satisfied through importing technology from other countries, mainly Europe and the USA, with the USA holding the largest stake in Mexico's import of environmental technology. Export of environmental technology from the USA to Mexico has been growing rapidly in the past years. The US International Trade Administration talks about "an unprecedented investment in environmental infrastructure, that gave Mexico an upward mobility by improving two points in the world ranking in the Environmental Technologies Top Market Study"[25].

The design and product specifications in the manufacturing and food and beverage industries predominately take place outside of Mexico in the headquarters of companies like Chevrolet, Volkswagen, Nissan, Dell, Nestlé, Unilever, Danone or Heineken. All these companies however are present in Mexico and give guidance to the Mexican manufacturers on how to produce, manufacture and assemble their products according to their production specifications. Mexico is in this respect a

[25] https://www.trade.gov/press/press-releases/2016/international-trade-administration-releases-reports-ranking-top-export-markets-052516.asp

follower of the international businesses operating in Mexico and will without any doubt follow when these companies opt to change the design of their products and production to fit circular economy processes and concepts. The overall economic situation in Mexico, and the trends for the future, shows a potentially positive transformation towards a circular economy. An important characteristic of the manufacturing sector is its international character, with perpetual flows of import and export in and out of Mexico. This can be seen as a potential for transformation process towards a circular economy.

2.7. REGULATORY FRAMEWORK AND PUBLIC PROGRAMMES SUPPORTING CE INITIATIVES

Mexico has 32 states, Mexico City recently being included, and has about 2454 municipalities. Its legal system is based on the European, and especially French, system, with a division between the legislative, executive and judicial branch. The legislative branch is comprised of a congress with a chamber of deputies and chamber of senators. The executive branch – the president, ministers and their administrative entities – are responsible for executing the laws enacted by the congress, and the judicial branch has the function of interpreting the laws and resolving disputes. On the federal level, the key administrative body responsible for environmental affairs is the Secretariat of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales*, SEMARNAT). Many environmental areas have special agencies with far-reaching authority to develop and execute politics, such as the National Water Commission, the National Commission for Protected Natural Areas or the National Institute of Ecology and Climate Change. Other areas are decentralised, such as the municipal waste management that largely is the responsibility of local and municipal governments. The differentiation and decentralisation of politics are seen as a positive development, but what is missing is a proper coordination between different institutions and levels of government (Gasnier and Portales 2008).

Despite of the obvious flaws in the Mexican political/legislative framework, there are also positive developments to be mentioned. For some years now, Mexico has developed a National Development Plan (NDP) to drive developments in a certain direction with clear objectives and goals. The National Development Plan 2013– 2018 was launched in 2012.

The words environment, sustainability or circular economy are not found among the five key objectives, but they are present as objective 4.4, under the heading of prosperity. Objective 4.4 of the national plan aims at stimulating "green growth", while the way to operationalise this is published in the "Sectorial programme for environment and natural recourses 2013–2018" (PROMARNAT), developed in parallel with the overall national plan.

The main law related to circular economy is the Fundamental Mexican Law, the 4th article of the Political Constitution of Mexico indicates, among other rights, that each person has the right to a healthy environment as part of personal development and wellness. It is the most important law in Mexico and no other laws must be against the rights recognized there.

Another important reference in the Mexican framework of circular economy is the National Plan for the government (2018-2024) which presents the action lines that federal government will implement around economic, political and environmental protection. It is relevant because the funds and financial resources of the government will be assigned according to this plan.

Recently the following laws are part of the body laws in Mexico to drive all actions related to circular economy:

- General law to prevent and integrate waste management.
- National vision to sustainable management: zero waste.
- General law of climate change.
- Hydric National Program.

Also, the Federal congress is working on law initiatives to enhance the environmental system in Mexico, some of them are related to circular economy topics as well as:

- Initiative to avoid plastic pollution of one unique use.
- Project of law to reform different norms of the General law to prevention and integral waste management.
- Initiative to modify the Protection to environmental law. Overview of the main challenges to the business opportunities in CE in Mexico

In chapter 2 of this document, we enter into the specific business opportunities in the solid waste, wastewater and waste to energy markets where Mexican and European companies can join forces to bring about positive changes, while making economic gains. However, there are several challenges or potential barriers to enter into the market which we highlight in this section.

2.7.1. WASTE COLLECTION, GOVERNANCE AND REGULATIONS

Waste management in Mexico is regulated under the General Law for the Prevention and Integral Management of Waste (LGPGIR). However, different authorities have control over the management of different waste fractions. For instance, urban solid waste is managed by municipal authorities; special handling waste is the responsibility of the state authorities meanwhile hazardous waste is controlled at federal level. In this sense, the municipalities are responsible for the provision of the public service for the: cleaning, collection, transfer, treatment and final disposal of waste where they have the budgetary and social burden to manage their waste. However, municipalities only have the legal authority over the solid urban waste and not over special handling waste or hazardous waste.

However, the municipalities' problems are compounded by the community and human settlement patterns, which are not specific to a precise area. For instance, there are communities that by their expansion can be established in two or more municipalities. For this reason, the waste collection and final disposal service must be shared as an urban basin with little authority over who is responsible for the waste collection. Furthermore, there is inequality in the coverage of the collection and disposal service at national level. Areas with a population greater than 10,000 inhabitants, have a service coverage of up to 80% on average, meanwhile areas of less than 10,000 inhabitants, have a service coverage only up to 23%[26]. On the other hand, there are 143 municipalities in Mexico that do not have any service at all. In this sense, the southern region, made up of Veracruz, Guerrero, Oaxaca and Chiapas, where there are more municipalities with a greater number of towns of less than 10,000 inhabitants, is the region with the lowest coverage (69%) of waste collection services.

[26] https://www.gob.mx/cms/uploads/attachment/file/435917/Vision_Nacional_Cero_Residuos_6_FEB_2019.pdf

Furthermore, the global market for secondary raw materials is also affected by decisions covering product regulations and economic regulations. In effect the Waste Industry and pioneering manufacturers in Mexico and Europe are operating in a poor regulatory framework that does little to support the recovery of secondary raw materials, one that generally stifles innovation. The problem of market failure in the recovery of secondary raw materials is being recognised in Europe, but the global nature of trade means wider solutions are needed. A new regulatory construct that moves from "waste" to the idea "materials management" or "materials reuse" is required. Regulations therefore remain a major barrier to circular economy progress. A regulatory framework is needed where materials have similar management controls/incentives based on their risk potential rather than seeing them as a waste. A clear lead in this regard can be taken from Europe where Sweden (best in class) is now at 0.7% to landfill.

2.7.2. LANDFILL OPERATION AND SOLID WASTE VALORISATION

In relation to the final disposal services and landfill in Mexico, an INEGI report in 2010[27] listed 238 sanitary landfills in which 70% of the waste generated is available for reuse or valorisation. Meanwhile out of a staggering 1,643 of the reported open dumps, only 25% of that waste is available for valorisation; the rest (5%) is waste that can be recycled without valorisation.

The operation of landfills and dumps is reported as being inadequate and representing a risk to the health of the population and the environment. The Contaminated Sites Computer System (SISCO) (operated by SEMARNAT) identified that at least 277 final disposal sites (landfills or open dump sites) present conditions similar to those of a contaminated site. Therefore, critical actions need to be undertaken in terms of sanitation or remediation at each of these sites to mitigate the risk posed to human and environmental health. The waste streams also need to be managed corrected to enable create the conditions for circular economy processes to exist.

2.7.3. LACK OF FISCAL OPPORTUNITIES

Finance is clearly critical in any change process as significant as a change from a linear to a circular economy. Since landfilling is still the predominant treatment route across Mexico and in virtue of the increase of municipal waste amounts in future, substantial investments are required to deliver a circular economy. A new financing approach to better tackle investment needs for this niche of projects in the solid waste sector is needed in which partnerships are built with key manufacturing and retailing industries. Although the Solid Waste sector is in a phase of growth that offers attractive opportunities for private and public investment the instability in secondary raw material prices will not be overcome without better partnerships with both suppliers of secondary raw materials and market users of the outputs.

Any fiscal change with new financing options, needs to be supported by regulatory change. For instance, if the use of primary raw materials is continually subsidized to a point where the economic advantage of using secondary raw materials is cancelled out, this will not drive market forces to change to a circular economy focus. Fiscal incentives are also required to ensure that business as usual for manufacturing companies becomes the most expensive solution as the real price of externalities is factored into the price of primary raw materials. There should be an aim that businesses in transition should face lower overall taxes, whilst those that continue with linear business approaches be provided with fiscal

[27] https://www.inegi.org.mx/temas/residuos/

incentives to change. Fiscal solutions in Europe have shown how landfill taxes drove change which has been rapid and has inspired radical new solutions and the emergence of new technologies.

With such an approach, the waste industry can be the catalyst that makes it possible for manufacturers and energy suppliers to use secondary raw materials as their main or substantive raw material supplemented by primary raw materials. Once manufacturers and energy suppliers take the step change it becomes powerful by putting the waste management industry at the centre of the change process.

2.7.4. THE FRAGMENTED MARKET

Across the EU the waste markets are fragmented. Coupled with the fractured methods of implementation they have created further barriers in an industry that now routinely moves recovered raw materials across global markets. In Europe financing institutions have been supporting comprehensive solid waste management schemes including different kinds of technologies. This fact is important as solutions found for the EUs fragmented markets will have wider relevance in Mexico. The EU is a global leader in the circular economy and any acceptance or change made in the EU will more than likely be mirrored by others including Mexico.

Further afield there is a current lack of international commodity markets for secondary raw materials. For such markets to work a series of changes need to take place in the way policy makers view and regulate waste. Without these changes, it remains a complex challenge to drive up recycling standards in rapidly urbanizing countries and to give confidence to designers to specify secondary raw materials. This was recognised in the original EU Resource Efficiency Roadmap.

Secondary raw material markets need to provide the same services as those currently operational for primary raw materials. That is markets were participants can expect to:

- buy and sell materials;
- have price transparency;

In an OECD[28] report prepared in 2006 they identified three potentially significant barriers and failures in markets for recyclable materials:

- have built in systems to protect against price fluctuations and “futures” trading;
- have regulatory certainty; and
- have computerised data and information systems to underpin that market.

Quality standards are fundamental to any commodity market. For secondary raw materials, common standards are needed that will work across Mexico and answer both regulatory (End of Waste) and market (Quality Requirements) questions. No designer will use secondary raw materials unless the properties of those materials are understood, the quality is guaranteed, and the supply chain is secure.

[28] OECD, (2006) Improving Recycling Markets, ISBN 9264029575.

2.7.5. LACK OF ACCEPTANCE

Public acceptance is a key component for the feasibility of using technologies in the circular economy. For instance, the public perception on the source of water and its end-use of recycled water is widely noted to impact public acceptance. This refers to the emotional responses to the idea of using recycled water, including "disgust" at the perception of the proximity to 'waste'. This has been cited as a key factor in the rejection of several reuse schemes globally. According to (Hartley, 2006) people are more likely to accept reuse of water from their own home than from a public source. This relates principally to what is called the "yuck factor". Generally, acceptance is higher when human contact with water is minimal. Application for industrial use therefore tends to be well accepted, which is the opposite to domestic use (van Rensburg, 2016). This has been no more evident than the rejection from the farmers in the Hidalgo municipal area. These farmers occupy the largest agricultural land in Mexico, where they have been irrigating with untreated wastewater for decades. The new massive $50m^3$/second wastewater treatment (the largest in the world, built in a single stage) was seen as an opportunity to treat the wastewater and to give the treated water back to the farmers for irrigation. The farmers rejected this water, forced the closure of the construction of the plant for over a year and created an association called the "Black Water Defenders". The reason they gave was that the water would contain less nutrients and that would force them to buy fertilizers which would increase the cost of their production. The lack of sensitization campaigns, education and capacity were the principle reasons to blame for the farmers to reject this circular economy solution.

3. SECTOR ANALYSIS

3.1. SECTOR ANALYSIS SOLID WASTE MANAGEMENT

3.1.1. SECTOR OVERVIEW: MEXICO

Municipal Solid Waste Generation

In 2015, Mexico already had a population of 119.9 million inhabitants, and it is estimated that the population will be 148.2 million people by the year 2050 (CONAPO, 2018). On the other hand, it will be 28.3 million additional people who will demand resources for their development such as including solid waste management (SEMARNAT, 2019). In addition, it is estimated that the Mexican states with the highest population growth will be: Quintana Roo, Baja California, Campeche and Querétaro, whose population in 2050 will be, respectively, 56, 51, 44 and 43 % higher than in 2018 (CONAPO, 2017).

If the trend of per capita waste generation continues, population increases will invariably bring with it an increase in the generation of solid waste in the country. Today Mexico generates around 44 million tons of Municipal Solid Waste (MSW) per year, which is the reason that sits in the 20 most waste generating countries (Figure 5). It is expected that this number will reach 65 million by the year 2030 (SEMARNAT, 2019).

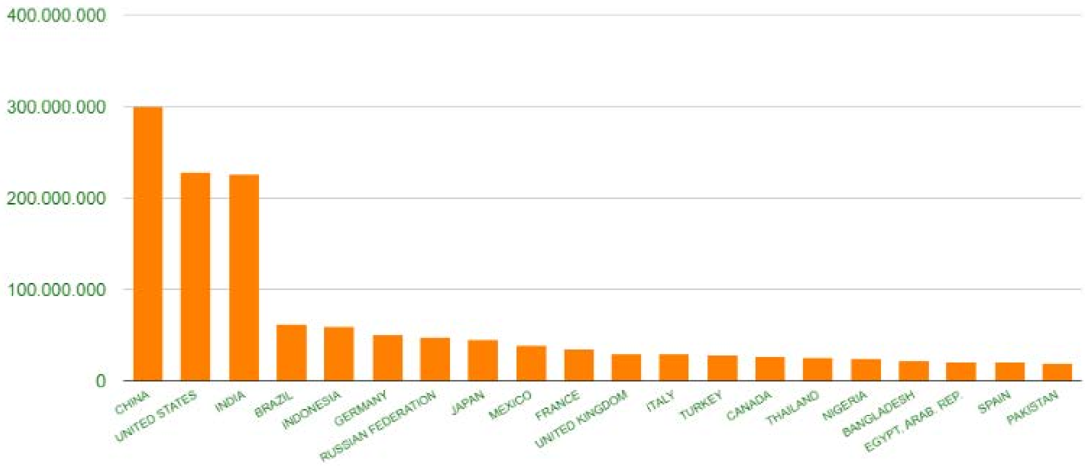


Figure 5. Municipal solid waste generation in the world Source: (Waste Atlas, 2019)

Waste generation also increases with urbanization. High income countries and economies are more urbanized, and they generate more waste per capita and more waste in total. Currently, Mexico generates 0.86 kg/hab/d on average (SEMARNAT, 2019), although some sources indicate that the generation rate per capita is 1.2 kg/d (Waste Atlas, 2019).

The highest average generation value per capita is found in the Northwest Region with a value of 1,51 kg/hab/d meanwhile the other regions have the following waste generation values: Northeast 0.83 kg/hab/d, Southeast 0.77 kg/hab/d, West 0.66 kg/hab/d, Centre with 0.65 kg/hab/d and South with 0.33 kg/hab/d.

Per capita generation of waste varies in relation to the different types of population and level of urbanization. In populations with more than 100,000 inhabitants, the detected rate is approximately 1 kg/hab/d but in a population less than 10 thousand inhabitants the generation can reach 0.4 kg/hab/d (INECC, 2012)

If the federal entities are classified by the volume of MSW produced, the five largest waste producers together generated a total of 45.7% in 2018: the state of Mexico (6.7 million tons, 16.1% of the national total), Mexico City (4.9 million ton, 11.8%), Jalisco (3.1 million ton, 7.2%), Veracruz (2.3 million ton, 5.5%) and Nuevo León (2.2 million ton, 5.1%) (SEMARNAT, 2018) (Figure 6).

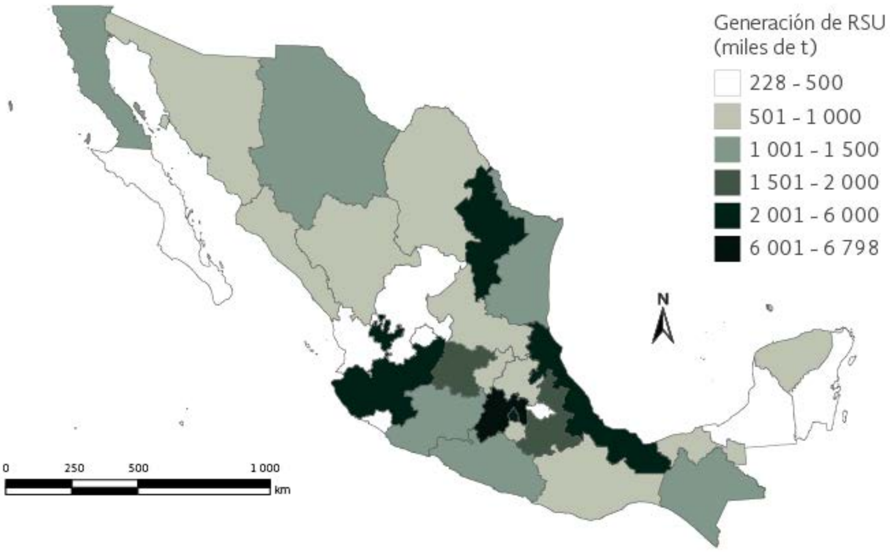


Figure 6. Waste generation by region in Mexico Source: (SEMARNAT, 2018)

Municipal Solid Waste Composition

The composition of urban solid waste is a parameter of importance in order to propose the optimal waste management strategy focused on the valorisation. Additionally, to calculate the dimensions of the waste treatment plants. The average volumetric weight of all MSW is 153 kg/m3 (SEMARNAT, 2018).

Mexico is migrating towards a waste composition with a lower predominance of organic waste: in the decade of the 50s, the percentage of organic waste ranged between 65% and 70% of its volume, while in 2012 this figure was reduced to 52.4%. However, important components of the waste produced in the country are also paper and its derivatives (13.8%) and plastics (10.9%) (SEMARNAT, 2018).

The recyclable fraction refers to any waste that does not have characteristics of organic waste and which can be susceptible to a process of recovery for its reuse and recycling. These fractions include glass, paper, cardboard, plastics, laminates of recyclable materials, aluminium and non-hazardous metals and others not considered as special handling waste (SEDEMA, 2013). Figure 7. gives an overview of the average composition of MSW in Mexico. The figure shows that 37.97% is made up of organic fractions, while 39.57% is made up of a recyclable fraction leaving 22.46% of other waste. This indicates the high potential for the concept of circular economy to be introduced into this sector as there are high amounts of organic and recyclable fractions in the MSW in Mexico.

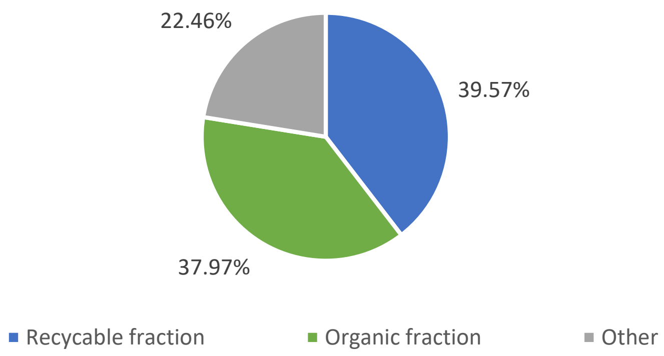


Figure 7. Average composition of MSW in Mexico Source: Elaborated by authors with data from (Salas Casasola, Islas Cortés, & Caballero Castrillo, 2016) & (INECC, 2012)

The composition of waste is expected to change over time, both qualitatively and quantitatively, which is to say that some fractions will become larger while others may decrease, and new materials will be added to the composition of the MSW stream, so a careful selection of technological options to provide adequate treatment solutions will be required (UN Environment, 2018). In 2012, Polyethylene terephthalate (PET) that is the preferable material for bottled drinks did not seem to be an important material in the MSW, see (Figure 8.), however currently PET is one of the most generated plastic materials (745,000 tonnes/year) and the most recycled plastic in Mexico. The recovery rate of PET in Mexico in 2016 was 57% with an average price of USD 18 cents/kg in bulk of the recycled PET (ECOCE, 2017).

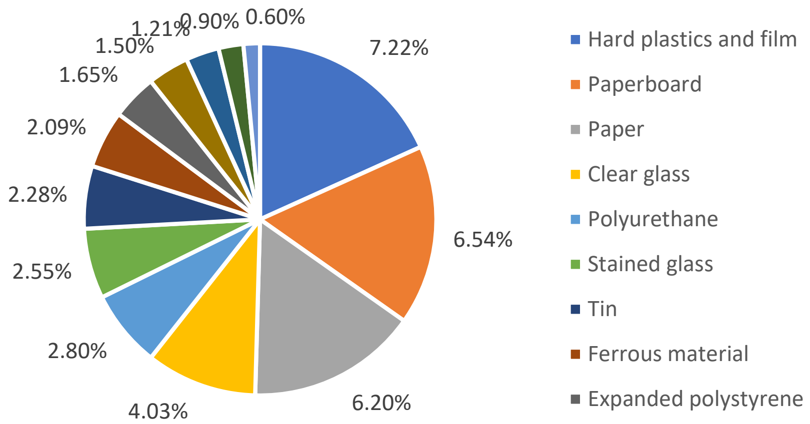


Figure 8. Materials that compose the Recyclable fraction of MSW in Mexico Source: Elaborated by authors with data from (INECC, 2012)

According to (INECC, 2012), in a more specific analysis by region, the largest percentage of organic waste present in MSW is found in the Northeast region (42.98%) an9d the highest percentage of recyclable waste is found in the Northwest at 54.79% (Figure 9. Meanwhile, the Southeast region of the country presents the highest percentage composition of the fraction of others (38.57%) i.e. the waste that cannot be recycled.

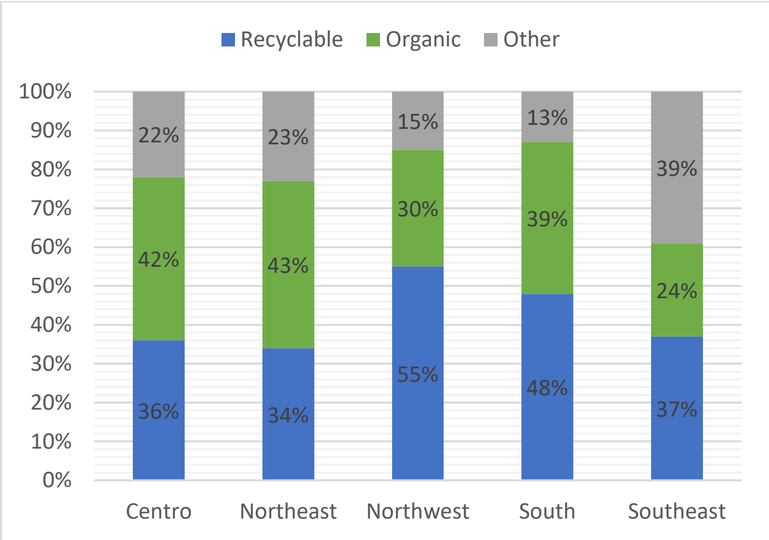


Figure 9. Regional composition of MSW in Mexico Source: Elaborated by authors with data from (INECC, 2012)

Municipal Solid Waste Collection

MSW collection is a complex activity and, in economic terms, it is one of the most resource-intensive urban cleaning systems in Mexico. Consequently, amongst other aspects of waste collection, it is of extreme importance that waste collection routes be adequately planned and designed to reach higher efficiency of collection coverages, whilst simultaneously reducing unnecessary greenhouse gas (GHG) emissions. In general, and just as in nations in other parts of the globe, there has been an increase in both service coverage and quality (UN Environment, 2018). The average national collection coverage in Mexico is 93.2% as of 2019.

Municipalities in Mexico are responsible for the collection, transfer, handling and final disposal of municipal solid waste. Nonetheless, municipalities do not charge fees for these activities, which entails a considerable weakness for the appropriate waste management cycle. Furthermore, there are no official standards or technical guidance for the collection, transfer and handling of waste. The final disposal stage is the only phase that is ruled by norms.

Given the collection as an indicator, it would be worth to highlight the States of Colima, Aguascalientes, Chihuahua, Distrito Federal, Nayarit and Quintana Roo show 100% collection coverage. On the other hand, States that report a collection rate less than 50% are: Baja California Sur, Guerrero and Puebla.

Selective or separate collection is a key step for providing continuity for the efforts of the generators who segregate the waste produced (segregation at source, or at the point of origin) so that they can go on through differentiated management. Thus, separating the waste can then be subjected to some form of treatment that will allow for valorisation and/or recovery, from waste that must be finally disposed of either given its characteristics and/or lack of market (UN Environment, 2018).

Until 2016, only 15% of waste collection in the country was selective; the entities that collected the largest volume of their waste in this way were: Mexico City (90% of the volume produced in the entity), Puebla (41%) and Yucatán (12%). In the same year, 16 federal entities did not carry out this kind of collection (INEGI, 2018).

The selective and separate collection of MSW is greater in the Western and Central regions, with 18.07 and 14.68% of the total collected. Special mention must be made of the Northwest Region, where the collection is still 100% mixed (INECC, 2012).

The highest percentage of separate collection is carried out in the municipalities with a population greater than 100 thousand inhabitants with 12.11%; while the lowest value is found in the municipalities with a population between 40 and 50 thousand inhabitants, with 1.72% (INECC, 2012) (See Figure 10.).

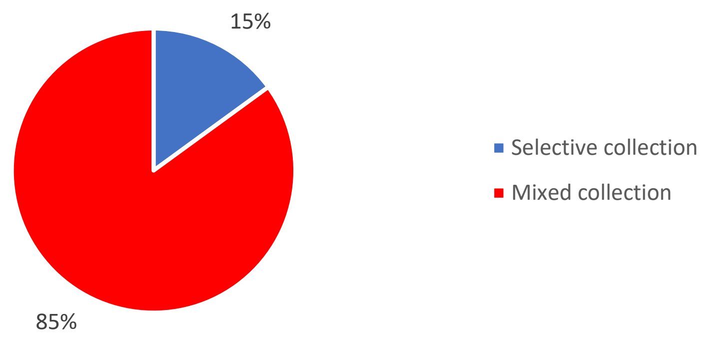


Figure 10. Ranking of mixed and selective collection in Mexico Source: Elaborated by authors with information of (SEMARNAT, 2018)

On the other hand, if Mexico intends to establish an integrated waste management system, it is key to know that historically, collection has been granted to citizens house-by-house, where only 2% (see Figure 11.) of those collected nationwide are made point by point in distributed containers (INEGI, 2018). It is therefore estimated that the cost of an integrated management system will be high mainly for this reason. Some attempts to establish selective point-to-point collection systems in the style of the "Puntos Verdes (Green Points)" such as in Spain have failed in some cases and in the end some municipalities have returned to provide the house-to-house collection system. In Mexico City for example, the collection works in a mixed way because although there is a collection system through trucks at times and points established by government, there are sweepers with carts that provide a house-to-house collection system informally financed by citizens through tips.

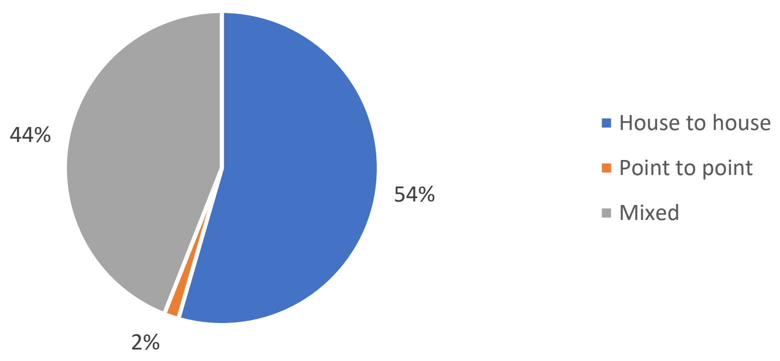


Figure 11. Prevailing collection systems in Mexico Source: Elaborated by authors with data from (INEGI, 2018)

Municipal Solid Waste Destination

According to the proportions indicated in the last national waste flow diagram published by official sources (INECC, 2012), adding the industrial collection (4.24%), the scavenging during the harvest (3.72%), the recovery of materials in sorting facilities (1.31%) and the scavenging in the sites of final disposal (0.36%) has a material recovery rate of (9.63%). It is noteworthy that more than 80% of the materials recovered in Mexico are achieved through the formal recovery of the industry and by informal scavenging during the initial stage of collection so it is recommended that any technical intervention in the sector considers these inclusion strategies or collaboration with the informal recycling sector in Mexico, especially to deal with the recovery of inorganic waste (See Figure 12.).

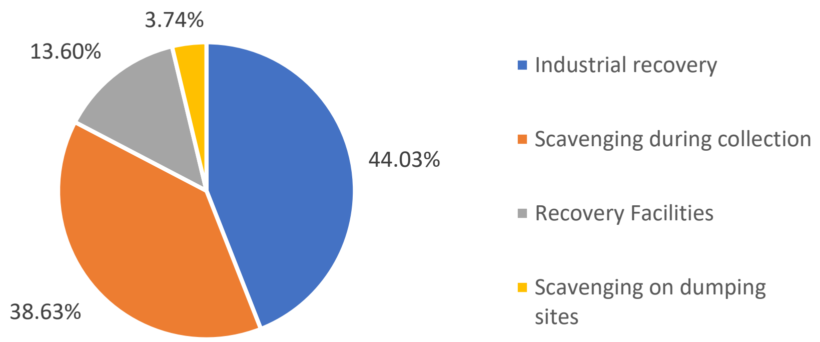


Figure 12. Contribution of Informal recycling sector to the recovery of MSW in Mexico Source: Elaborated by authors with data from (INEGI, 2018) & rates from (INECC, 2012)

At the national level, Mexico has around 133 waste transfer stations (INEGI, 2018). Only 30% of the transfer stations was designed to perform material recovery, 20% are known to have been designed to perform compaction of the waste received, but almost 60% are used only as material transfer stations to reduce transportation costs to the final disposal sites.

There is a record of 1,060 collection centres (INEGI, 2018) and furthermore there are hundreds of centres more distributed throughout the country which are not registered in the municipal data. Despite this, it is estimated that almost 14% of the solid waste generated (6 million tons per year) end up in clandestine dumps, rivers, lakes, beaches, forests and other ecosystems. Additionally 16% of MSW ends up in open dumps (7 million tons per year) and 60% that reaches controlled sites (27 million tons per year) is not 100% disposed in sanitary landfills that accomplish all the requirements of the Mexican regulations (INECC, 2012), so there is a large unattended market to provide integrated waste management services (see Figure 13.). The market is mainly open to attend to the organic fraction because the percentage of treatment to that kind of material in Mexico is not even considered and the generation is around 17 Millions of tons a year (INEGI, 2018).

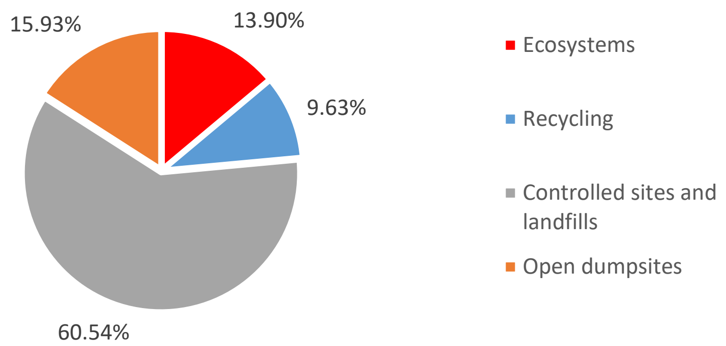


Figure 13. Final destination of MSW in Mexico Source: Elaborated by authors with data from (INEGI, 2018) & rates from (INECC, 2012)

Special Handling Waste

Municipal solid waste is one of several waste streams that countries and cities manage. Other common waste streams include industrial waste, agricultural waste, construction and demolition waste, hazardous waste, medical waste, and electronic waste, or e-waste. Some waste streams, such as industrial waste, are generated in much higher quantities than municipal solid waste. For the countries with available industrial waste generation data, the trend shows that globally, industrial waste generation is almost 18 times higher than municipal solid waste. Generation of industrial waste rises significantly as income level increases.

Table 2. depicts an overall view of the most representative special handling waste and basic information on the average generation, percentage of the annual average re-use and the percentage of the final disposal.

Table 2. Main types and data on special handling waste in Mexico

Special handling waste	Average generation (million tonnes per year)	% of Annual average re-use	% of final disposal (in sanitary landfills or controlled sites)
Agri-plastics	313.13	NA	NA
Manure (just from porcine and milk cattle)	66,708.27	NA	NA
Fisheries	799.02	3.67	NA
Waste from the Mexico City airport	8.04	32.20	67.43
Sludge (municipal wastewater treatment plants)	232.00	NA	100
Self-service shops (Wal-Mart)	407.19	67.97	32.03
Construction and demolition	6,111.09	NA	NA
Home appliances	21.66	NA	NA
Electronics	263.85	NA	NA
End of life vehicles (vehicles/year)	805,202.50	NA	NA
Tyres	1,011.03	NA	NA
Glass	1,142.57	NA	NA
Batteries	33.98	3.13	NA
Paper and cardboard	6,819.83	48.59	11
Waste from hotels	276.22	1.49	98.51

Source: Elaborated by authors with data from (INECC, 2012)

Hazardous waste

In Mexico, there are 106.450 hazardous waste generators of which 6,8% are large, 35,2% are characterized as small and 58% as microgenerators. Large generators are responsible for 94,7% of the hazardous waste, while 4,6% of the toxic waste is generated by small generators and 0,6% by the so called microgenerators. The most frequent waste generated are solid waste (44%), used oils (20,5%), and sludge (8%) (SEMARNAT, 2018).

Management strategies for hazardous waste (See Figure 14):

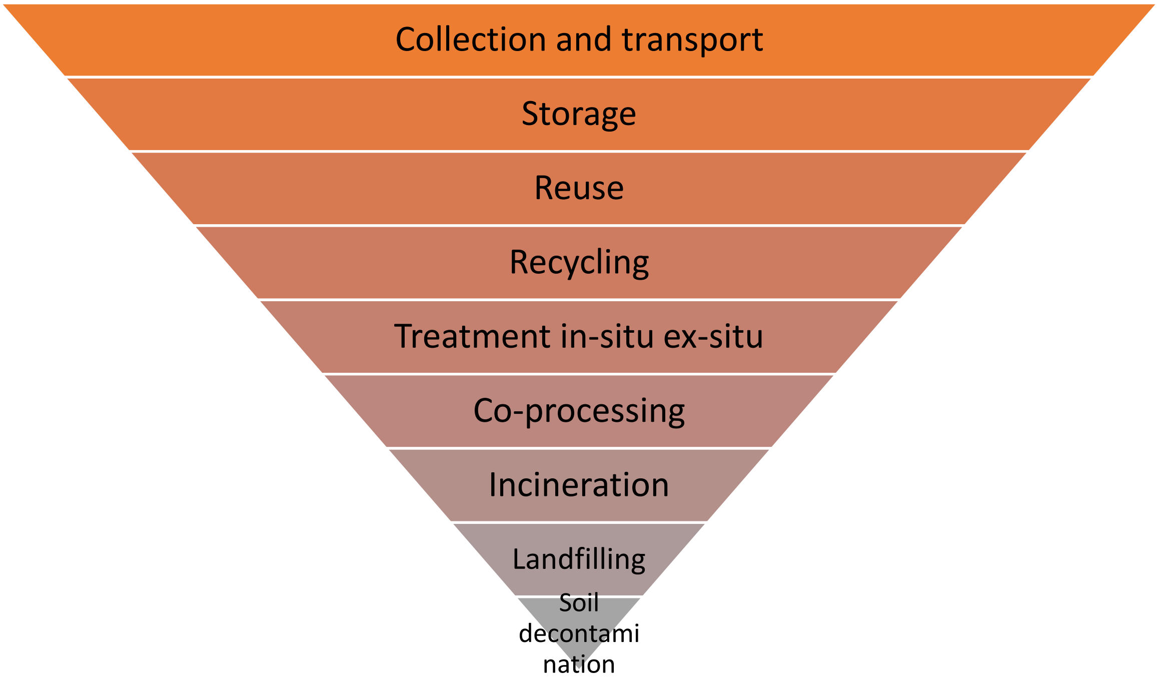


Figure 14. Management strategy for hazardous waste in Mexico Source: (SEMARNAT, 2018)

When taking a long-term perspective of the management of hazardous waste, between 1999 and 2014 in Mexico, the installed capacity to recycle, reuse, treat, incinerate or confine hazardous waste was approximately 21,07 million tonnes. Of this amount 46,4% was treated, 45% recycled, 5% confined, 2,5% reused and 1,1% incinerated. A promising trend is that in 2014 61,1% of waste was recycled, 36,4% treated and only 0,04% was incinerated (SEMARNAT, 2018). If this current management strategy can be sustained over time this could substantially increase the circularity of hazardous waste management in Mexico.

3.1.2. MARKET OVERVIEW

3.1.2.1. MARKET SIZE

The Solid waste market in Mexico can be divided into two main aspects where most of the opportunities are concentrated, namely: Municipal Solid Waste and Special Handling Waste. The overall market size for these two sectors are included below. In table 4 below, the technologies related to each of these Solid waste management sectors are identified and their needs expressed.

3.1.2.1.1. MUNICIPAL SOLID WASTE

The size of the urban solid waste management sector in Mexico is one of the most important in LATAM. As reviewed in previous sections, the total generation of MSW is 44 million tons per year. On average, the cost of solid urban waste management (collection and final disposal) is USD 30 per ton, then the Mexican market is worth USD 1,320 Million per year.

The collection of solid waste is mostly provided through the municipalities although the main cities as Guadalajara, Monterrey, Puebla, Queretaro, Pachuca, Cuernavaca, etc. are already served by some private collection company, at least partially. The quantity of companies that provide formal large scale of collection services are less than ten and in the most of cases they provide integrated collection and final disposal. The biggest 5 companies in this sector are VEOLIA, PASA, TECMED, RESA and RED Ambiental.

Regarding the collection and recycling stage, SEMARNAT prepared a Directory of Collection Centres for Waste Materials in 2010, in order to provide the general public with relevant information on the proper handling of the materials we consume and dispose of; also on the ways to separate them, manage them and dispose them properly, helping this work with a list of collection centres and recyclers of different materials in Mexico which gives us an idea of the size and importance of the sector (SEMARNAT, 2010).

3.1.2.1.2. SPECIAL HANDLING WASTE

Not only is there a large market in the MSW sector, as, the generation of industrial waste is almost 18 times higher than municipal solid waste. The generators of Special Handling Waste in Mexico must have a "Management Plan" and contract specialized management services for these materials that can be around USD 60 per ton, only for collection and final disposal, representing a market of more than USD 20 billion per year.

More importantly are the investment opportunities that can be found in the application of circular economy principles to special handling materials generated by industry and communities in Mexico, not only because the volume but the quality and price of materials that are possible to recover and maintain in the economic system. For example, the electronic waste problem is colossal, and it's growing, but at the same time it's an interesting investment opportunity. In 2018, Mexico generated 1,2 million tonnes of e-waste (UNU-IAS, 2015), of which 11.64 thousand tonnes were estimated composed by mobile phones[29], less than 2.5% was recovered by "Programa Verde" so almost 110 millions of mobile phones are disposed every year, with each unit containing components worth over USD 100 (Ellen Macarthur Foundation, 2018). This represents a potential of USD 1 billion of value that could be recovered each year.

Increasing building materials recycling and reuse, as opposed to landfilling the waste generated by construction and demolition (CDW) activities requires an investment of up to USD 200 Million per year to scale up the number of CDW recovery plants in the main 10 cities of Mexico.

Knowing if the technologies are mature, established, incipient or not available gives us an insight of where the potential for technologies are potentially required. Table 3 gives a key to the description of the situation of the technology.

Table 3: Criteria used to describe the situation of the different waste management technologies

Situation of the technology	Description
Mature	Has a presence of more than 50%
Established	Is present in between 5% and 50%
Incipient	Available, but used in less than 5%
Not available	Not used

[29] With data from (Ellen Macarthur Foundation, 2018) and estimations by authors

Table 4: Level of implementation of the technologies involved in different treatment processes

Stage	Technology	Level of implementation
Solid Waste		
Management	Integrated Waste Management Data Systems	*Incipient*
Storage	Special containers for automated load	*Incipient*
	Bins hidden in street furniture	*Mature*
	Smart containers	*Not available*
	Eco-points	
Handling	Shredders, crushers, chippers	*Established*
	Pulpers	*Not available*
	Pelleting & briquetting	*Not available*
	High compaction balers	*Incipient*
Collection	Data systems	*Not available*
	Garbage trucks with automated front, rear and side loading systems	*Mature*
	Mini rear loaders	*Not available*
	Multi-compartment vehicles	*Incipient*
	Optical multiplexer sorting systems	*Not available*
	By density sorting systems	*Not available*
Sorting & recovery	Magnetic separation systems	*Established*
	Trommels and screens	*Established*
	Conveyors	*Mature*
Food waste and OFMSW[30]		
Composting	Windrow turners, mixers, drum screens, grinders and separators	*Established*
	Vessel composting systems	*Not available*
	Household scale composting	*Incipient*
Biomaterials	Technologies to convert organic waste streams into new materials: food, fibers, agricultural and pharmaceutical inputs	*Incipient*
Plastic waste		
Transform and valorization	Mechanical recycling lines	*Mature*
	Chemical recycling systems	*Not available*
	Up-cycling technologies	*Not available*
Construction & Demolition Waste		

[30] Organic Fraction of Municipal Solid Waste

Recycling	Integrated recycling lines and equipment: Crushers, Screens & stackers	*Incipient*
Electronic waste		
Recycling	Integrated e-waste management from collection, process and recycling schemes	*Not available*
Tyres		
Recycling	Upcycling to produce asphalt paviment, running tracks and urban furniture	*Incipient*

With the information from the previous table, in Table 6 below we detail the technologies and opportunities for each of the stages of waste management.

The level of each particular need is classified between **high**, **medium** and **low/not required**. Table 5 describes each level and the symbol used in the classification in each sector analysis.

Table 5. Classification criteria used for level of need of the different technologies

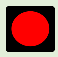
Level of need	Description	Symbol
High	Technology does not exist or has just one or two examples of implementation	
Medium	Technology is developed, there exists local demand and it is implemented in many cases although costs are high and technology enhancements are needed	
Low/Not required	Local technology is available and implemented across a wide range of examples with a low cost	

Table 6 Market needs in terms of innovation/technology/solutions

Stage	Technology	Level of need	Description
			Solid Waste
Management	Integrated Waste Management Data Systems		aboftware and data management services focus on reducing cost and risk at the same time as improving performance of municipal and private waste management services. Blockchain and big data technologies could have significant relevance in the next years.
Storage	Special containers for automated load		To enter this sector, integrated collection services should preferably be offered through the constitution of Regional Operating Organizations
	Bins hidden in street furniture		
	Smart containers		

	Eco-points		
Handling	Shredders, crushers, chippers		Shredding systems are used to reduce the size of a given material. In the recycling sector, there is a requirement for shredders for specific applications as: bulky waste, hazardous waste, domestic, biomass, kitchen waste, electronic, animal carcass, medical, tyres, plastics, paper, garden garbage, etc.
	Pulpers		The level of wood fibre, pulp and waste paper have remained at high levels in Mexico. New efficient pulpers can reduce production costs and also serve new customer basis.
	Pelleting & briquetting		Biomass briquette fuel technology is one of the main directions of biomass conversion and application technologies and therefore there is a high need for this technology in Mexico.
	High compaction balers		Baling is a process that compresses material into a block (bale) which is secured by plastic or wire strapping. Baling reduces the volume of waste product, which has several benefits. Today Mexican market is ready to implement screw compactors which is the technology for processing polystyrene (EPS) fish boxes, fruit boxes and other types of EPS packaging.
	ControlControl and automation		Intelligent process technologies with sensors and measurement devices gathers data from machines and processes.
Collection	Garbage trucks with automated front, rear and side loading systems		Similar to a front-end loader, the waste is compacted by an oscillating packer plate at the front of the loading hopper which forces the waste through an aperture into the main body and is therefore compacted towards the rear of the truck. This technology is mainly used in collection routes *point by point* as long as 1000 houses per day.
	Mini rear loaders		Usually used for commercial or residential waste hauling routes. In Mexico, some little towns and important touristic cities such as Guanajuato needs these trucks to collect the refuse through its numerous narrow streets without losing productivity.
	Multi-compartment vehicles		Designed to allow collection of multiple residential trash streams or recyclables in the same route.
Sorting & recovery	Optical multiplexer sorting systems		There are some technologies which use different physical principles and automatic systems to separate by size, density, type of material, colour, kind of metal, etc. As in the sorting lines, the materials are identified but using automated systems which sort and separate the waste then store and sometimes conditioning to recycling or valorisation. The optical multiplexer technology is in high demand in Mexico.
	By density sorting systems		
	Magnetic separation systems		
	Trommels and screens		
	Conveyors		
Food waste and OFMSW[31]			

[31] Organic Fraction of Municipal Solid Waste

Composting	Windrow turners, mixers, drum screens, grinders and separators		Turning compost improves ventilation, enables re-watering and ensures mixing of the different rotting areas in the windrow. To attain a compost of uniform particle size, and to separate off any contraries still present, the compost is screened. There is a wide range of mobile and stationary drum and star screening machines for this process.
	Vessel composting systems		These systems ensure that composting takes place in an enclosed environment, with accurate temperature control and monitoring. There are many different systems these include: Containers, Silos, Agitated bays, Tunnels, Rotating drums and Enclosed halls.
	Household scale composting		Common electric composting units are in high demand in Mexico
Biomaterials and bioproducts	Hydrothermal, Fermentation, pyrolisis, chemical		Facilities that sustainably generate products of commercial interest using only biomass as a substrate. Technologies to convert organic waste streams into new materials: food, fibers, agricultural and pharmaceutical inputs
			Plastic waste
TransformationTransformationTransformation and valorization	Mechanical recycling lines		Mechanical recycling is a method by which waste materials are recycled into "new" (secondary) raw materials without changing the basic structure of the material. It is also known as material recycling, material recovery or, related to plastics, back-to-plastics recycling (European Bioplastics e.V., 2015).
	Chemical recycling systems: pyrolysis, gasification, chemical depolymerization, catalytic cracking & reforming, and hydrogenatio.		Chemical, or feedstock, recycling is a general term used to describe innovative technologies where post-consumer plastic waste is converted into valuable chemicals, to be used as fuel or raw materials by the chemical industry (Plastic Recyclers Europe, 2019). This technology is in demand in Mexico.
	Up-cycling technologies		In Mexico, there is a need to transform by-products and waste materials from items that are otherwise useless or unwanted as plastic waste and transforming them into new materials or products of better quality or for better environmental value.
			Construction & Demolition Waste
Recycling	Integrated recycling lines and equipment: Crushers, Screens & stackers		Many applications require only simple manual sort conveyors with a variety of available economical component options designed to separate material elements by size, weight, magnetism and visual inspection. Mobile crushers and screens are the most common and prefered technology to recycle concrete from C&D waste streams.
			Electronic waste
Recycling	Integrated e-waste management		Hydrometallurgical method. This process is mainly used for profitable recycling of metallic fraction. In this method, metal

	from collection, process and recycling schemes		contents are dissolved into leaching solutions such as strong acids and alkalis. This is followed by electrorefining of desired metals.The Biometallurgical separation method has been used for recovery of precious metals and copper from ore for many years however in Mexico this process is not well developed. Biological micro-organisms transfer metal ions into the cells for their intracellular functions by binding metal ions present in the external environment on their cell surface is also an area of opportunity in Mexico
		Tyres	
Recycling	Upcycling to produce asphalt paviment, running tracks and urban furniture		Processing is required to make tires usable as a modifier or additive. The steel and fibre must be removed from the tires and then the remaining tire must be reduced in size to small particles for blending into the asphalt binder or mixture. The two primary processes are ambient grinding and cryogenic fracturing that are required in Mexico.

3.1.3. CONCLUSIONS AND RECOMMENDATIONS

The solid waste management sector in Mexico represents a significant market for technology and service companies around the world either because of the size of the economy as a whole or because of the size of the industrial sectors who inevitably require an integral management of the materials that circulate through their value chains. Given that the main innovations in circular economy models are emerging from European and that there is a strong and historically successful business relationship between the EU and Mexico this represents a significant opportunity for both Mexico and Europe.

Less than 10% of the 44 million tons of MSW per year and less than 1% of the almost 900 million tons of special handling waste per year receive treatment in Mexico, which means there is a significant unattended market.

— Almost 95% of MSW is collected, mostly with equipment in poor conditions or not suitable for selective or differentiated collection. The need for technology is clear. Some areas within Mexico are still using animals to carry out collection meanwhile in parts of the world autonomous refuse trucks are in full operation.

— Significant changes in MSW policy is expected from the recent publication of the National Vision towards sustainable management: “Zero Waste” by SEMARNAT. In general terms, through this document, Mexico defines that the transition to the circular economy will be achieved through the formalisation of the "Operative Organisms" of waste so it is expected that there will be multiple Public-Private Associations in the following years. The door to investments is therefore open.

— In terms of Special Handling Waste, there is a requirement for multiple composting technologies and scales to recover nutrients from food waste and organic fraction of MSW but at the same time Mexican start-ups are innovating in the process to extract high value biomaterials to use it in pharmaceutical and health industry from Agri-wastes and they need technological and services partners from Europe to scale up and develop new business models.

- The volume of C&D waste is also sharply increasing, reflecting the pace of infrastructure development across Mexico. The latest report from SEMARNAT indicates that 6.5 million tones of C&D waste is produced annually in Mexico.
- E-waste is now the fastest-growing waste stream in the world. Sobering, only 20% of global e-waste is formally recycled the remaining 80% is often incinerated or dumped in landfills. The Mexican national average generation of this type of waste in 2006 was of 263,849 tonnes, which represented a per capita generation of 2.52kg/hab/year. The number of mobile devices in the Mexican market has increased from 14 million in 2000 to 107 million until the first semester of 2016. This growth has raised concerns amongst mobile phone operators, device manufacturers and consumers for the adequate disposal of devices and accessories.
- There are 28,900 million tyres disposed of every year in Mexico. The Mexican tyre market is very peculiar due to the proximity to the US and its close connection to the used automobile market. Aside from producing and importing new tyres, Mexico imports from the US used tyres to be used on vehicles in Mexico (1,065,000 units in 2012; 3.7 % of the national market), furthermore it also imports used tyres for rethreading (1,082,000 in 2012).
- Currently, in Mexico, 5% of tyres are recycled, 2% are used for energy generation, 2% are disposed in authorized collection centres and the remaining 91% are abandoned or used without control.

Finally, Mexico in 2009 had a waste equipment market of 806 Million Euros, in 2019 this is expected to be around 1300M Euros and then it is expected to grow at 6% to 2025.

3.2. SECTOR ANALYSIS WASTEWATER TREATMENT AND REUSE

Introduction

Implementing a paradigm shift in the water sector to move from linear to circular economic models is directly related to wastewater treatment. The quality of wastewater from anthropic activities (urban, industrial, agricultural, etc.) is generally affected by different processes that prevent this water from being reused directly for different outcomes. Moreover, wastewater often has levels of contaminants that are harmful for fluvial ecosystems as well as for natural and human activities that take place downstream. Thus, reutilization of urban, industrial or agricultural wastewater requires the accomplishment of a series of water treatment goals.

Considering the importance of wastewater treatment, technologies and infrastructures have been developed with the aim of satisfying social, legal and environmental demands. These technologies have different degrees of complexity that subsequently require different levels of investment. As a consequence, establishing these technologies around the world is highly dependent on the economic resources available in each country or region. However, social and environmental requirements are much more homogeneous and therefore there is a concern, mainly in developing countries, with regards to the achievement of acceptable water quality levels with relatively affordable wastewater treatment technologies. In practice, the quality achieved from wastewater treatment around the world is extremely diverse. The different national regulations further compound the homogeneity of these technologies and processes.

The global change in temperature and rainfall patterns related to climate change show an increase in temporal and spatial heterogeneity in water resources. This fact together with demographic and social trends, causes water scarcity problems in many areas, that subsequently need to develop new adaptation techniques to their changing environment. Mexico shows a highly variated spatial distribution of both population and rainfall and therefore represents a good example of this problem. Considering these concerns, the field constitutes an important source of market opportunities where collaboration between international companies and the sharing of knowledge and resources can lead to productive and symbiotic relationships.

Water is one of the main drivers for many human and environmental processes, subsequently wastewater treatment and reuse represents a key component to achieve sustainable development. Therefore, efficient water management is crucial to achieve Sustainable Development Goal 6 (Clean water and sanitation). According the SDGs index, Mexico's score of 52.6 out of 156 countries, is stagnating around 50% of the required rate to attain the indicators of SDG 6 (see Table 7). The circular economy approach can be an important asset to achieve SDG 6.

Table 7: Mexico`s indicator results for SDG 6

6 CLEAN WATER AND SANITATION	Population using safely managed water services	42,6 %
	Population using safely managed sanitation services	45,2 %
	Freshwater withdrawal (%)	24,1 %
	Imported groundwater depletion (m3/year/capita)	8,6

In the EU it is estimated that the proposed CE instruments related to water ("A Blueprint to Safeguard Europe's Water Resources" (COM (2012) 673). A Fitness check of EU Freshwater policy (SWD (2012) 393) published in November 2012) could lead to water reuse in agricultural irrigation in the magnitude of 6,6 billion m^3 per year, as compared to 1,7 billion m^3 per year in the absence of any EU legal framework. Re-using more than 50% of the total water volume theoretically available for irrigation from wastewater treatment plants in the EU would avoid more than 5% of direct abstraction from water bodies and groundwater, resulting in a more than 5% reduction of water stress overall. Acting now would contribute to alleviating water stress where it is already a reality today in the EU and also prepare operators and farmers to be ready to act also in those parts of the EU which will experience increasing water stress in the coming years and decades.

3.2.1. SECTOR OVERVIEW MEXICO

Mexican Constitution states that water services as supply, drainage, sewerage and treatment are a responsibility of the municipalities. In Mexico, there are around 2500 operators that provide services to one or more municipalities. Technical, commercial and financial competences are very diverse amongst them. A number of deficiencies has been detected: change of managers when there are changes in municipal government; lack of qualification in workers; insufficient tariffs; infrastructure in bad conditions; lack of a unique and clear regulative and legal framework; lack of transparency and social participation; political interests in water managers. In order to solve these problems, privatization of these operators has been proposed. Latest initiatives in the General Water Law (Ley General de Aguas, 2015, 2017) go in this direction. For the moment, most of the municipal operators keep their public character despite the initiatives at the local, national and international level (World Bank), but public character of water management in the next years will be conditioned by the necessary reinforcement of the municipal operators.

Precipitation in Mexico is around 1,500,000 million m^3/yr. There are 50 main rivers that collect 87% of the total country's surface runoff and the area of their catchments accounts for 65% of the country's mainland surface area. According to CONAGUA (The National Water Commission), 70% of rainfall is lost through evapotranspiration, leaving a natural water availability of 475 km^3 (surface runoff and infiltration). This represents an average of 4505 m^3/hab·year. This average value is higher than in some European countries such as Spain (2800 m^3/hab·year), Germany (1870 m^3/hab·year) and France (3370 m^3/hab·year), mainly due to the density of population. However, spatial distribution of water resources is very heterogeneous in Mexico. While the southeast region has a natural availability of 13290 m^3/hab·yr, the rest of the country has only 1835 m^3/hab·yr. 68% of available water is found in regions with only 23% of the population and generating 15% of GDP whereas 32% of the available water is found in regions with 77% of population that generates 85% of the GDP. These figures show that there is indeed regions and states in Mexico with significant water stress, this consequently generates a need for sustainable and efficient management and the implementation of water reuse schemes.

Figure 15. shows the predicted water stress levels in Mexico in the year 2020:

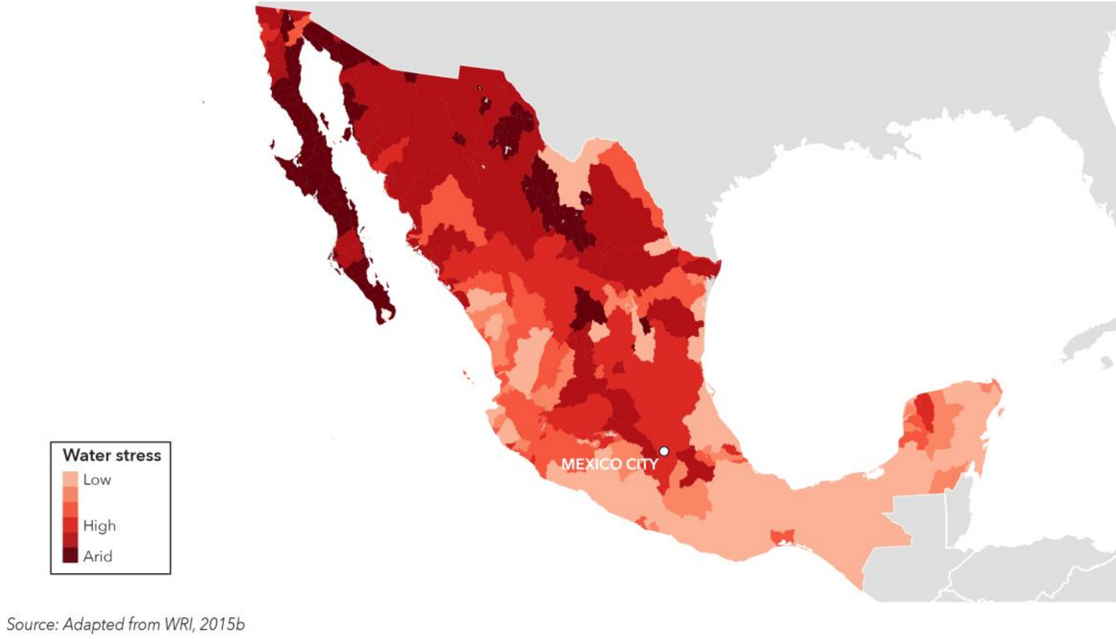
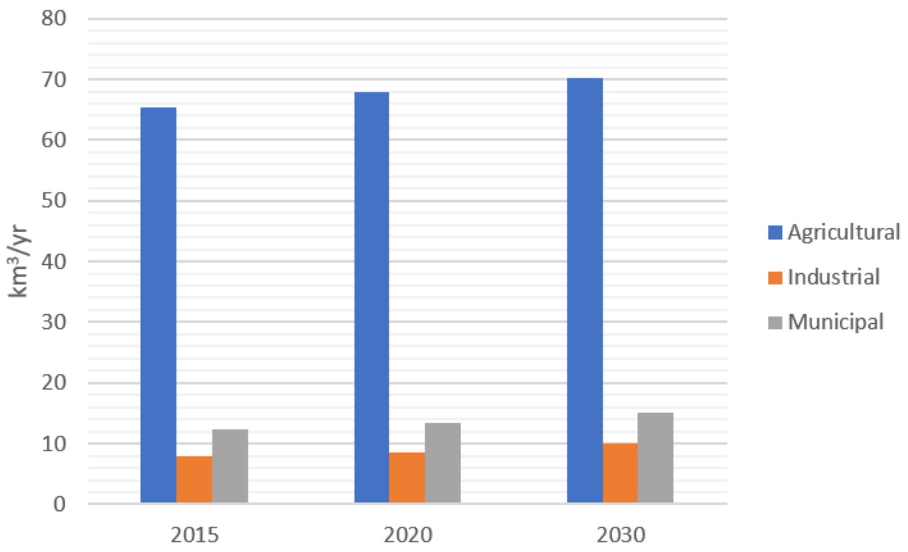


Figure 15. Distribution of water stress in Mexico (Source: GWI)

Global trends indicate increasing water stress from south to north and from east to west. The most arid regions are in Baja California peninsula. Water stress is a consequence of the available water resources and the existing demand, which is a consequence of demography and industrial volume. The level of water stress is an indicator of the needs of improved management and the opportunities for water treatment and reuse technologies. Therefore, regions in the north and west are more likely to be the aim of potential projects and market opportunities.

Current water resources (data from 2014) show a predominance of surface water, that represent 72.8% (402 km^3/yr) of the total water resources (552.9 km^3/yr). On the other hand, groundwater resources represent a volume of 150.0 km^3/yr (27.2%).

With regard to water withdrawals by sector, Figure 16. shows the trends from 2015 until 2030:



Sector (km³/yr)	2015	2020	2030
Agricultural	65.34	67.90	70.19
Industrial	7.90	8.57	10.05
Municipal	12.40	13.38	15.19
Total	**85.64**	**89.85**	**95.43**

Figure 16. Future projection of water demand for agricultural, industrial and municipal uses

Water withdrawals increase in the three sectors: agricultural, industrial and municipal uses. The total increase from 2015 until 2030 represents a 11.4%, divided in partial raises of 7.4%, 27.2% and 22.5% for agricultural, industrial and municipal uses respectively.

Apart from water stress, Mexico has steadily increased its water and wastewater coverage, according to CONAGUA, the potable water sewerage coverage in 2015 accounted for 94,4% and 91,4%, respectively (CONAGUA, 2018). Despite this progress, almost nine million people still lack clean water (five million in rural areas) and 11 million lack sewage (7.8 million in rural areas). However, Mexico only treats 50.3 % of all the collected urban waste water and 16% of industrial wastewater. Since 1994 (first records of wastewater statistics) Mexico has dramatically increased its wastewater treatment capacity from 546 treatment plants to 2892 treatment plants installed across the country (2014) with a treatment capacity of 151 m^3/s. This clear improvement has resulted in a need for increased water sector investment as well as improved water resource management. Furthermore, although there has been an increase in the number of wastewater treatment plants installed since 1994, there is a significant number of these plants that are in disrepair or are need of an upgrade. Therefore, significant investment is required to bring these installed plants up to standard.

Table 8 shows gives a statistical overview of the wastewater sector in Mexico. Focus is set on wastewater treatment as it represents the sector with a major link with circular economy:

Table 8: General indicators of wastewater management in Mexico

Wastewater indicator	Value	Source
Total Number of WWTP	2892 (2337 in operation)	CONAGUA 2014
Design capacity of WWTP	151,88 m^3/s	CONAGUA 2014
Wastewater collected	91,4 %	Estadísticas del Agua en México, 2018
Collected wastewater treated to secondary level	84,6 %	GWI 2010
Collected wastewater treated to tertiary level	0,002 %	CONAGUA 2014
Length of sewer network	116,100 km	GWI 2010

3.2.2. MARKET OVERVIEW

3.2.2.1. MARKET FORECAST

CONAGUA's existing programmes will try to achieve better utility efficiency and performance over the next years. However, the sector will be highly dependent on the evolution of legislation. National level infrastructure investment efforts will mainly be focused on water supply projects, including aqueducts and desalination plants. Despite the contract value of these projects will be high, the number of initiatives will be low. While increasing the country's wastewater treatment coverage is a long-term target, besides refurbishment of existing plants, near term projects to increase installed capacity have not yet been articulated by CONAGUA. The decrease in oil prices has made it necessary to look for private sector investment in developing planned water projects.

Water companies will increasingly find opportunities in the growing industrial sector. Contracts have lower values than in the municipal sector, but there will be a higher frequency of them. Municipal treatment plants are not likely to employ advanced technologies, whereas industrial sector will require more sophisticated water treatment solutions to meet the increasing enforcement of wastewater discharge regulations.

Based on data published by CONAGUA in their annual reports an evolution baseline has been set for the period 2015-2020. Although investment in water infrastructure remained essentially constant over the last decade, there has been significant investment in wastewater, with a peak of 1.7 billion € in 2012 (GWI, 2017).

Nevertheless, it is expected that wastewater networks will be the focus of investment in the future to connect the population to existing wastewater treatment plants. Wastewater treatment is one of the main Mexico's environmental priorities, as it is the least developed part of Mexico's water sector. It must be noted that National Water Programme, released in 2013, sets treatment goals of 100 percent for municipal waters by 2030.

Utility wastewater capex shows an expected increase of 16% in 2020 compared to the base values at the date of release of the National Water Programme in 2013, raising to a value of around 1644€ million. Most of this increase is related to wastewater networks, whereas increase in sludge management is lower in absolute values and capex is approximately constant for wastewater treatment plants.

Concerning equipment capex, the increase in the same period is a 30.2% (from 2573.5€ million to 3369.5€ million). Most of this amount is associated with water utilities. The equipment capex related to industrial uses remains around 15% of the total value for the whole period, keeping pace with the increase in utility capex.

Operational expenses also show a steady increasing trend during the analysed period, although the raise is more significant for industrial uses (20.6%, from 1035.3€ million to 1249.2€ million) than for wastewater utilities (8.3%, from 731.8€ million to 792.3€ million).

Investment in desalination shows a sharp increase in the last years, raising from around 3.6€ million in 2015 to over 71.1€ million at the end of the decade. This trend is expected to change to a more stabilized situation in the following years.

Table 9 shows the potential capital expenditure and operating expenditure classified by sector and by technology for the period 2013-2020. Data corresponding to water supply sector have been included to provide a general view of the expenses of the whole water cycle:

Table 9. Capital and operational expenditure in water sector for the period 2013-2020

Capital expenditure by sector ($m)	2013	2014	2015	2016	2017	2018	2019	2020
Utility water capital expenditure	**857.3**	**925.2**	**1,052.6**	**1,047.8**	**1,122.0**	**1,199.8**	**1,284.7**	**1.362.3**
Water networks	399.5	261.0	312.9	453.8	473.8	494.6	527.7	563.0
Water treatment plants	186.4	132.9	159.3	231.0	241.2	251.8	268.7	286.6
Water resources (excl. desalination)	246.4	521.4	574.3	346.5	361.8	377.7	403.0	429.9
Seawater and brackish water desalination	25.0	10.0	6.2	16.6	45.1	75.6	85.3	82.7
Utility wastewater capital expenditure	**1,583.0**	**1,618.9**	**1,643.9**	**1,681.6**	**1,708.6**	**1,748.2**	**1,794.8**	**1,848.6**
Wastewater networks	1,001.6	1,031.7	1,062.6	1,094.5	1,127.3	1,161.1	1,196.0	1,231.9
Wastewater treatment plants	445.2	449.8	434.2	435.2	423.2	422.4	430.8	443.7
Sludge management	136.2	137.4	147.1	151.9	158.1	164.7	168.0	173.1
Industrial capital expenditure	**454.8**	**450.6**	**423.5**	**412.6**	**459.8**	**503.9**	**541.5**	**579.8**
Total capital expenditure	**2,895.2**	**2,994.6**	**3,120.1**	**3,142.1**	**3,290.4**	**3,451.9**	**3,621.0**	**3,790.7**
Capital expenditure by technology ($m)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Oil-water separation	50.3	53.9	32.9	29.6	29.6	35.1	38.6	41.1
Suspended solids removal	267.9	240.5	246.0	277.0	287.7	300.9	316.5	332.5

Dissolved solids removal	34.6	25.9	23.2	26.7	40.3	53.5	59.1	60.3
Biological treatment	227.5	231.6	226.4	227.1	225.0	226.3	231.9	240.1
Disinfection	34.6	27.1	31.2	41.3	44.0	46.3	49.2	52.4
Sludge management	133.6	136.7	146.9	152.5	160.9	169.4	174.8	181.8
Total technologies	**748.6**	**715.7**	**706.6**	**754.1**	**787.5**	**831.4**	**870.1**	**908.2**
Intakes/outfalls	108.9	96.2	98.2	112.6	123.1	135.7	144.9	151.7
General construction/other	390.1	368.7	365.5	380.6	416.7	451.3	479.3	506.0
Networks & resources	1,647.5	1,814.0	1,949.8	1,894.7	1,963.0	2,033.5	2,126.7	2,224.8
Total capital expenditure	**2,895.2**	**2,994.6**	**3,120.1**	**3,142.1**	**3,290.4**	**3,451.9**	**3,621.0**	**3,790.7**
Operating expenditure by sector ($m)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Utility water	2,376.3	2,413.5	2,448.1	2,483.1	2,518.7	2,553.5	2,588.8	2,624.1
Utility wastewater	823.3	838.8	843.9	855.6	863.1	873.2	881.8	891.3
Industrial	1,164.7	1,203.5	1,234.1	1,251.1	1,281.1	1,331.3	1,363.8	1,405.3
Total operating expenditure	**4,364.3**	**4,455.8**	**4,526.1**	**4,589.7**	**4,662.8**	**4,758.1**	**4,834.4**	**4,920.7**
Operating expenditure by segment ($m)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Labour (in-house services)	1,795.7	1,827.8	1,852.3	1,878.5	1,906.0	1,938.8	1,966.0	1,995.5
Energy	467.9	477.2	484.3	494.2	503.7	514.2	524.3	534.9
Parts & consumables	267.4	272.6	276.7	280.7	284.7	289.3	293.3	297.6
Chemicals	262.8	268.5	272.2	275.8	280.6	286.8	291.6	297.0
Third party services	536.2	558.4	576.5	581.2	594.6	621.2	637.2	659.2
Oil & gas water services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	1,034.2	1,051.2	1,064.2	1,079.2	1,093.2	1,107.8	1,122.0	1,136.5
Total operating expenditure	**4,364.3**	**4,455.8**	**4,526.1**	**4,589.7**	**4,662.8**	**4,758.1**	**4,834.4**	**4,920.7**

3.2.2.2. WASTERWATER TREATMENT TECHNOLOGIES

The classification of the current wastewater treatment technologies is considered based on the following processes for wastewater treatment:

Preliminary Treatment: removal of large objects, grit and grease to avoid problems in more advanced treatment technologies.

Primary Treatment: removal of some suspended solids and organic matter

Advanced primary Treatment: enhanced removal of suspended solids and organic matter, usually through chemical addition or filtration

Secondary Treatment: removal of biodegradable organic matter (in solution or suspension) and suspended solids. Disinfection is typically also included in the definition of conventional secondary treatment

Secondary with nutrient removal / recovery: removal of biodegradable organic matter, suspended solids and nutrients. Nutrient removal principally nitrogen, phosphorus or both

Tertiary Treatment: removal of the remaining suspended solids. Typically achieved through filtration. Tertiary treatment also includes disinfection. Nutrient recovery is more often included in this stage rather than in secondary treatment.

Advanced: specific treatment level required for certain applications. It involves the removal of total dissolved solids and/or trace constituents. This type of treatment is normally focussed on industrial wastewater treatment.

Based on this classification Table 11 summarizes the technologies that are used in Mexico for different wastewater treatment processes and the availability or level of implementation for each type of technology (third column). It should be noted that normally, technologies in the industrial sector are included in the secondary and tertiary treatment process and technologies for advanced treatment are included only under tertiary treatment. The different categories are shown in Table 10

Table 10: Criteria used to describe the situation of the different wastewater technologies

Situation of the technology	Description
Mature	Has a presence of more than 50%
Established	Is present in between 5% and 50%
Incipient	Available, but used in less than 5%
Not available	Not used

Table 11: Level of implementation of the technologies involved in different treatment processes

Treatment process	Technologies	Level of implementation

Primary treatment	Septic tanks	Mature
	Primary sedimentation tanks and chemically enhanced sedimentation	Mature
	Imhoff tanks	Mature
	Anaerobic/facultative ponds	Mature
Secondary treatment	Activated sludge	Mature
	Up flow anaerobic sludge blanket (UASB)	Established
	Trickling filter	Established
	Rotating biological contactor	Incipient
	Anaerobic Digestors / Anaerobic filter	Established
	Biological reactor	Established
	Land treatment (maturation ponds; aerated ponds; wetlands)	Mature
Tertiary treatment	Micro-filtration	Not available
	Ultra-filtration	Incipient
	Nano-filtration	Established
	Reverse osmosis	Established
	Membrane bioreactors	Incipient
	Ion-exchange	Established
	Chemical oxidation	Incipient
	Granular media filtration (sand, carbon filters)	Established
	Disinfection (ultraviolet, ozone treatment and chlorine disinfection)	Mature
	Nutrient removal and recovery	Incipient
	Land treatment (soil aquifer treatment; maturation ponds)	Mature
	Modular wastewater treatment plants	Incipient

Linked to the treatment processes, the following technologies are used for energy exploitation related to wastewater:

(i) **Micro-algae bioreactor**: can be used to produce fuels such as biodiesel and bioethanol, to generate animal feed, or to reduce pollutants such as NO_x and CO_2 in flue gases of power plants
(ii) **Anaerobic digestion**: industrial or domestic purposes to manage waste or to produce fuels
(iii) **Codigestors**: addition of substrates that produce higher levels of biogas

Finally, monitoring and control technologies complement the ones directly involved in wastewater treatment. A common indicator that describes the degree of implementation is the level of automatization of the control and monitoring operations, as it is linked to the quality of the obtained data.

As a global pattern, technologies used in urban wastewater treatment in Mexico are antiquated. The plants using tertiary or advanced treatment processes are rare. On the other hand, Mexico has made great advances in industrial wastewater treatment, where private money is paying for advanced technologies for water reuse (GWI, 2017).

The problems related to urban wastewater treatment are generally linked to the lack of maintenance of the technologies involved.

Table 12: Percentage of use for wastewater treatment technologies in Mexico

Technology	Percentage of application (%)
Land treatment (maturation ponds; aerated ponds; oxidation ditches; wetlands)	36,63
Activated sludge	30,34
Septic tanks	9,33
Up flow Anaerobic Sludge Blanket (UASB)	7,02
Biological treatment	3,51
Anaerobic/facultative ponds	3,04
Imhoff tanks	3,00
Enzyme reactor	2,40
Primary sedimentation tanks and chemically enhanced primary sedimentation	1,33
Granular media filtration (sand filters, carbon filters)	0,26
Others	0,34

3.2.2.3. MARKET NEEDS BY TECHNOLOGY TYPE

From an international point of view, spending on suspended solids removal and biological treatment systems will dominate as a consequence of their importance in industrial and urban wastewater treatment, which constitutes a growing sector, specifically with relation to water reuse.

Oil/water separation technologies is an important feature in refinery and petrochemical effluent streams and, to a limited extent, in pharmaceutical and power industries.

Suspended solids technologies are being promoted due to tightening regulations, an increasing reliance on poorer quality water resources and the growth of municipal and industrial water markets. The biggest market is the municipal sector and especially in the Asia Pacific area.

Dissolved solid removal techniques (e.g. reverse osmosis, multi-stage flash, multi-effect distillation, Ion exchange are beginning to play an important role as steps in wastewater treatment, particularly zero liquid discharge solutions. These technologies are promoted by stricter environmental restrictions and greater industrial needs that enhance the production of wastewater.

Biological treatment techniques are enhanced by tightening regulations and is becoming increasingly visible in Asia, particularly in China and India. These techniques are predominantly used in the food & beverage and pulp & industries. Other drivers are the growing interest in generating biogas and requirements associated with an increase in water reuse.

Disinfection/oxidation techniques (e.g. chlorination, ultraviolet, ozone) are driven by a switch from chlorination to non-chemical processes, the improvements in UV and ozone reactors and tighter regulations and water reuse. These techniques are particularly used in industries as food & beverage, pharmaceuticals and microelectronics, as well as to remove hard-to-treat contaminants in flowback water and mine tailings.

Sludge management techniques (e.g. landfilling, incineration, land spreading, deep well injection disposal) are being promoted by the increase in sludge production worldwide, the interest to reduce the volume of sludge, the tightening of environmental regulations and government initiatives, the interest for energy recovery and sludge reuse, limitations in landfill capacity and public perception.

In this section, the market opportunities related to the technologies involved in the wastewater treatment sector in Mexico are discussed. The level of each particular need is classified between **high**, **medium** and **low/not required**. Table 5 describes each level and the symbol used in the classification below.

Apart from wastewater treatment technologies themselves, network efficiency is a key element to guarantee the development of this sector. Concerning this point, pumping technology is crucial. Growing demand for water pumps is currently attributed to growth in agricultural and residential sectors, together with growth in end-use industries. Water and wastewater treatment industry is the largest end user of water pumps and is nowadays showing a significant growth. Industrialization, urbanization and rise in tariffs are also expected to enhance growth in global water pumps market. The main gaps are seen in SMART pumps with integrated sensors and GPS systems.

— ***Primary treatment***

The market is extensive in the sector of septic tanks. The establishment of enhanced septic tanks with filter media or nutrient recovery can enhance water reuse, which will reduce stress on the current water sources. The adaptation of industries to the increasingly restrictive legislation can also be facilitated by the use of septic tanks.

The need for primary treatment technologies is summarized in Table 13:

Table 13. Level of need of primary treatment technologies

Technology	Level of need	Description
Septic tanks	🟡	Need to update the existing plants with enhancing filter media. CONAGUA has identified the need to update the existing wastewater treatment plants. Septic tanks is an area where they will look to improve the situation all around the country
Primary sedimentation	🔴	No market gaps
Imhoff tanks	🔴	No market gaps
Anaerobic/facultative ponds	🔴	No market gaps

— ***Secondary treatment***

There is a field of potential optimization in different configurations of the activated sludge process to maximise its efficiency. Currently, the largest wastewater treatment facilities use non-membrane secondary process. Therefore, there are opportunities for optimisation and improvement of technologies. These modifications also include energy recovery.

The need for secondary treatment technologies is summarized in Table 14:

Table 14. Level of need of secondary treatment technologies

Technology	Level of need	Description
Rotating biological contactor	🟢	There are few examples of this technology in Mexico. Therefore, there is large potential for implementation, especially in small villages
Activated sludge	🟡	Being the most common technology in Mexico (555 plants), Conagua seeks to upgrade these plants. The applicability of this technology is especially important in sensible receptor environments. Suitable for a wide range of population sizes
Up flow Anaerobic Sludge Blanket (UASB)	🟡	Potential for nutrient removal technologies. Especially suitable in areas with moderate to high temperature (coastal zone). Less energy needs and small sludge formation compared to conventional treatments (appropriate in big cities)
Anaerobic digesters / filters	🟡	Increasing conscience for energy recovery. Suitable in small communities where can constitute energy supply mean and it is easier to have space availability
Biological reactor	🟡	Latest technological improvements make possible efficiency gains. Potential of implementation in small villages. Higher water quality and small footprint so suitable for vulnerable environments.
Land Treatment	🟡	Advances in wetland technologies can take opportunities in urban wastewater treatment, conditioned to space availability. Suitable in urban areas due to less odour generation
Trickling filter	🔴	Less efficient technology and rare in Mexico

— *Tertiary treatment*

Opportunities linked to tertiary treatment technologies are motivated by the objectives of nutrient recovery, increasing energy efficiency and water reuse. Moreover, these technologies allow for wastewater to be treated at source, therefore decreasing the cost of transport. These technologies meet the more exigent requirements stated by new regulations.

The need for tertiary treatment technologies is summarized in Table 15:

Table 15. Level of need of tertiary treatment technologies

Technology	Level of need	Description
Micro-filtration	🟢	Nowadays no wastewater treatment plants use this technology despite its large potential. Wide pH range, long life cycle, good price/performance ratio and heat resistance. High potential in the whole country due to wide range of temperature and water conditions and recent development.
Reverse osmosis	🟢	

Ultra-filtration		Gaps associated with needs in water reuse, especially for urban wastewater utilisation in industry. Reverse osmosis is principally used in desalination (large installation of desalination plants in Mexico in the last 20 years). Nano-filtration used principally for industrial water treatment
Nano-filtration		
Chemical oxidation		Combined with other technologies, great potential for heavy metals removal in urban wastewater. Potential use in treatment of urban industrial areas. Suitable in presence of organic pollutants
Membrane bioreactors		Potential around the country for adaptation to new regulations that require higher quality in wastewater. Nutrient recovery systems become more necessary
Nutrient removal and recovery		Reducing polluted groundwater sources of nitrates and providing a source for lacking phosphorous are two drivers for its implementation. Adaptation to new regulations
Modular wastewater treatment plants		Opportunities in rural areas, hospitals, hotels and housing developments)
Ion-exchange		The technology exists but is promoted by a national shift to low carbon technologies
Granular media filtration		Technology used in two new treatment plants
Disinfection		Opportunities come from the increase in secondary treatment without membrane processes
Land treatment		Technology used for urban wastewater treatment. Advanced technologies lead to opportunities for water reuse

Apart from water treatment technologies energy conversion technologies linked to wastewater sector show also good market opportunities. Mexican Energy policy states that by 2024, 35% percent of its energy should come from renewable sources. Also, automated control and monitoring has also a market opportunity associated to the implementation of new technologies and the goal of improving the system’s efficiency.

3.2.3. CONCLUSIONS AND RECOMMENDATIONS

Wastewater management is a key aspect to be considered when shifting from a linear to circular economy model at the national level. Anthropogenic activities affect the quality of wastewater; therefore they threaten ecosystems and prevent water from being used directly for other purposes. Thus, wastewater management requires certain treatment objectives to be achieved.

The water sector in Mexico is overseen by the governmental institution CONAGUA, which establishes the guidelines and planning that concerns the water infrastructures and regulations. Despite the improvement in recent years, work is still to be done especially considering a demographic evolution which shows an increase in population in some specific areas. Within this framework we provide an insight into the market opportunities that can be the origin of relationships of collaboration between European and Mexican companies. The main points related to market opportunities in the wastewater sector are summarized as:

- Demographic evolution shows a progressive increase of population in urban areas, therefore making necessary an adaptation of wastewater treatment procedures
- Climate patterns in Mexico show a great spatial heterogeneity. Water stress is higher in the northern and western regions, therefore becoming areas with high potential for new treatment and reuse initiatives and projects
- SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales) and its dependent institution CONAGUA (Comisión Nacional del Agua) are the organisms responsible of launching tenders and adjudicating winning proposals and funding wastewater projects in Mexico. Therefore, these will be the main institutions to liaise with for European entities looking to work in Mexico.
- Companies will increasingly find opportunities in the growing industrial sector. Contracts here have a lower value than in the municipal sector but there is a higher frequency of projects.
- Wastewater treatment plants in Mexico do not typically use advanced technologies but more sophisticated water treatment solutions will be needed to meet the increasing enforcement of wastewater discharge regulations
- It is expected that wastewater networks will be the focus of investment in the future to connect the population to existing wastewater treatment plants
- The highest potential for implementation of new technologies is found in tertiary treatment processes
- National planning sets an objective to treat all the wastewater by the year 2030. This ambitious objective should reinforce the number of projects in this sector and related market opportunities
- The situation of the sector in recent years has shown some uncertainty in the development of regulations due to social and political pressure. This point needs to be considered when establishing market strategies that must adapt to national regulation

3.3. WASTE TO ENERGY SECTOR ANALYSIS

Introduction

The transformation of waste into energy, whether it is thermal or electrical, is increasingly becoming a part of municipal, state, national and regional systemic approaches. On the one hand, it increases resource efficiency and diminishes the need for external fuel sources, and on the other, it adds profitability to waste management infrastructure, which can be expensive and difficult to execute by governments alone, especially those in developing economies who spend a larger portion of their budget on such investments as well as O&M (World Bank, 2018). All potential waste to energy interventions should be looked at in terms of long term and short-term business opportunities as there could be potential for the waste to be transferred into another added value produced which does not undermine local supply.

The sourcing of waste that can be utilized for energy generation is quite varied, for example the following have been identified as areas for potential energy sources.

1. Municipal solid waste (organic and inorganic)
2. Industrial
3. Electronic
4. Construction and demolition
5. Agricultural and agribusiness (of vegetable and animal origin)
6. Food industry oils and fats
7. Domestic, industrial and municipal wastewater
8. Gaseous losses
9. Energy losses due to inefficiencies in power generation or transformation

Therefore, the methods for transforming these above-mentioned wastes to energy vary significantly in complexity, GHG emissions (a high price to pay when considered part of a renewable energy matrix), and the potential return on investment. Nevertheless, this sector analysis focuses on providing valuable insight into the existing opportunities in Mexico for Original Equipment Manufacturers (OEMs), project developers, technical advisors, as well as funding partners, given the current market conditions.

Special attention is focussed on the sectors which have been identified by previous studies as those with the most promising outlook, such as agricultural solid waste, MSW (including food waste), wastewater treatment, and waste heat recovery for cogeneration. (GIZ, 2016; SENER, 2014)

3.3.1. SECTOR OVERVIEW: MEXICO

Since 2008, Mexico has undergone a series of structural reforms to promote the use of waste as an energy source, while incentivising the reduction of GHG emissions. The Energy Transition Law (LTE) signed in 2015, stated that 25% of the energy generated must come from clean energy sources by 2018, 30% by 2020, and 35% by 2024 (DOF, 2015). To reach these objectives, the barriers that limit the exploitation of renewable energy sources must be overcome. In 2013, energy generated from waste only contributed to 1.39% of the total Mexican energy consumption (SENER, 2014). However, the energy potential from residual biomass in 2016 was estimated at 1,070 PJ, corresponding to 12% of the total energy mix (Table 16)

Table 16. Energy potential for different biomass residues. [Source: REMBIO, 2016]

Waste Source	Amount Generated Mt/yr	Energy Source	Energy Potential PJ/yr
Agricultural	60	Solid Biomass combustion	450
Agroindustry	17	Solid Biomass combustion and	125
Animal	-	Biogas	305
Municipal	-	Biogas	190

As the sector with the most potential, the biogas sector in Mexico is still in its early stages with the most value coming from the wastewater treatment sector, where high-end technologies have been successfully implemented at large scale. The agricultural sector has the most biogas plants in the country, but it has the most cases of failure due to a rapid growth lacking proper technical assistance. Momentum is building for a 400 ton/day of OFMSW biogas plant in the Municipality of Naucalpan, State of Mexico that is being backed up with feasibility studies funded by US-United States Projection Agency and GIZ. If this project moves forward, it will serve as a model for MSW biogas plants in Mexico. Specifically, as landfills represent a relatively unexploited source of biogas in the country which presents an opportunity for growth.

The recent decision of the Mexico City government to back out from a 30-year contract to build and operate the first large scale Thermovalorization plant in the country will potentially set back the waste to energy sector in Mexico. However, lessons learned from this case can set the course for a similar project in one of the other large metropolitan areas of the country.

3.3.1.1. SECTOR TECHNOLOGIES, TRENDS AND MARKET SIZE

This section explores the different technologies that can obtain energy from waste sources, namely biogas, biodiesel, and combustion. Emphasis is given in describing the level of adoption and current trends of these technologies by the different waste producing sectors in Mexico.

This section explores the different technologies that have been used in Mexico to obtain energy from waste sources, namely biogas, biodiesel, and combustion. Emphasis is given in describing the level of adoption and current trends of these technologies by the different waste producing sectors in Mexico. Table 18 summarizes the level of adoption of the Waste to Energy technologies for each of the applicable sectors according to the criteria specified in Table 17.

Table 17: Criteria used to describe the situation of the different WTE technologies.

Situation of the Technology	Description
Mature	Has a presence of more than 50%
Established	Is present in between 5% and 50%
Incipient	Available, but used in less than 5%
Not Available	Not used

Table 18: Level of implementation of the technologies involved in different WTE processes.

Sector	Technologies	Level of Implementation
Biogas	Upflow Anaerobic Sludge Blanket (UASB)	Established
	Expanded Granular Sludge Bed (EGSB)	Established
	Anaerobic Lagoon (AL)	Mature
	Continuously Stirred Tank Reactors (CSTR)	Incipient
	Dry Digesters	Not Available
	Ultra-Dry Batch Digesters	Incipient
	Landfills	Mature
Biodiesel	Advanced Biodiesel	Incipient
Combustion	Palletization	Incipient
	High Power Technologies	Established
	Low Power Technologies	Established

- Biogas

Biogas can be burned to produce thermal, mechanical or electrical energy. The biogas electricity sector in Mexico has a very low installed capacity compared to its potential as shown in Figure 17 below.

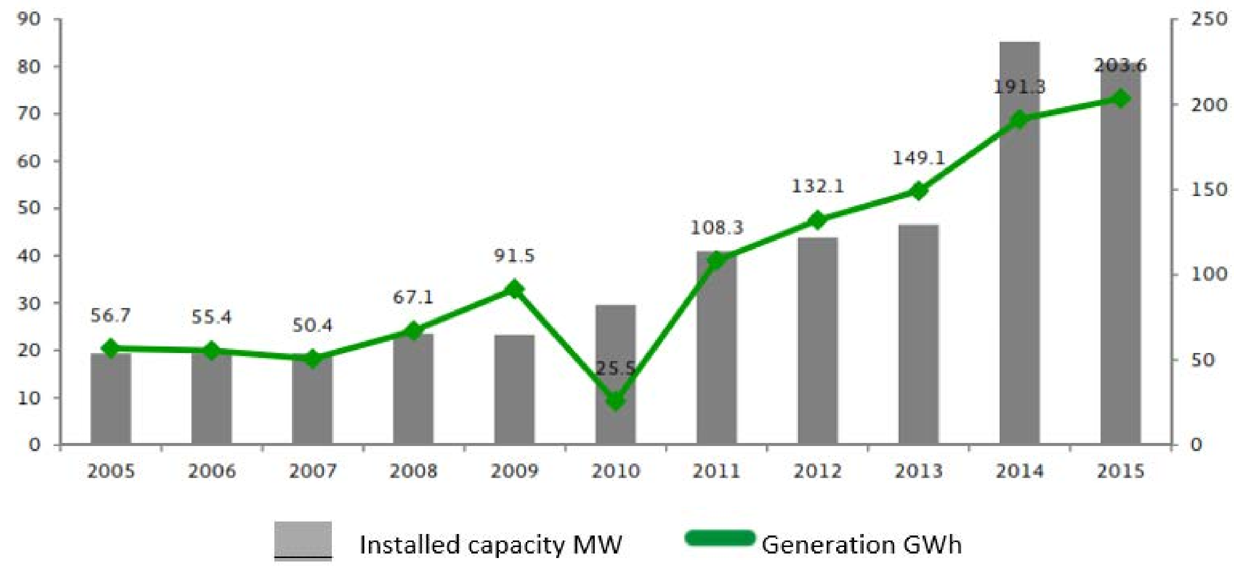


Figure 17: Biogas installed capacity and output for Mexico. [Source: SENER, 2016]

- Wastewater Anaerobic Reactors

The two main technologies utilized in Mexico are the Upflow Anaerobic Sludge Blanket (UASB) and the Expanded Granular Sludge Bed (EGSB).

Upflow Anaerobic Sludge Blanket (UASB): This type of reactor is widely known to work well in the treatment of municipal wastewater in Latin America with adoptions rates of 30% in Brasil, 20% in Colombia, and 10% in Mexico (Noyola et al., 2012). At least 180 UASB reactors were in operation in WWTP in Mexico in 2012. The typical construction system employed in Mexico consists of multiple uncovered reinforced concrete cells of about 1,000m^3/cell.

Expanded Granular Sludge Bed (EGSB): This type of reactor demands careful monitoring performed by highly skilled operators. EGSB reactors are not recommended for implementation in municipal WWTP in Mexico due to the requirement of skilled labour, but it is proven and a recommended option in industrial WWTP (II-UNAM 2013). EGSB projects have been adopted by Grupo Bimbo (bakery and sweets), Cuauhtémoc Moctezuma (brewery), Empaques Modernos San Pablo (paper) (IB-Tech 2019).

Wet Digesters

This type of digester can handle substrates with moisture contents of 85% and higher, such as animal manure runoff and wastewater treatment residual sludge. There are two, very distinct types of wet digesters found in Mexico: Anaerobic Lagoon (AL) and Continuously Stirred Tank Reactor (CSTR). There are about 1,500 AL digesters installed mainly in the states that have swine farms of Sonora and Yucatan, and the dairy regions of Durango, Coahuila and Jalisco. Mexico has 16 Municipal WWTP with installed CSTR digesters, and Atotonilco's WWTP has by far the largest of the CSTR capacity with 390,000 m^3.

Anaerobic Lagoon (AL): This is the digester of choice in the agricultural sector given its suitability for treatment of animal manure, its low investment cost, and relatively simple operation. It is estimated that more than 1,500 anaerobic lagoons have been installed in Mexico (USAID 2015) predominantly in the swine and dairy regions of Sonora, Jalisco, Yucatan, Durango, Coahuila, Guanajuato, and Puebla. The construction of AL in the Mexican Agricultural sector started in 2005 as a result of the Clean Development Mechanism (CDM) financing. Given that manure treatment in Mexican swine and dairy farms is mostly done in uncovered anaerobic lagoons which emit high amounts of GHG, and the low investment cost of a GHG mitigating covered anaerobic lagoon, Mexican farms became a very attractive opportunity for CDM investors. By 2013, a total of 640 agricultural biogas plants were built under this scheme (USAID 2015), in which operation and maintenance was performed by the CDM project investors. However, a global over supply of CERs paired with reduced industrial activity in Europe, caused the price of CERs to trade below 3 USD/ton in 2012 compared to 20 USD/ton in 2008 (CDM Policy Dialogue, 2012). As a result, agricultural biogas plants were handed over from CDM investors to farm owners. Due to the lack of knowledge from the farmers in operating biogas plants, many of these projects ceased operations within a few years.

A positive effect of the CDM project in Mexico was the increased awareness of biogas technology among large scale swine and dairy farmers. As a result, The Mexican Secretary of Agriculture and Rural Development (SAGARPA) and its financing trust the Fideicomiso de Riesgo Compartido (FIRCO) started promoting biogas technologies in the agricultural sector in 2008 by subsidizing up to 50% of the total investment cost of biogas plants. By 2013, a total of 317 were built under this scheme (USAID 2015). Due to low value of CERs, these plants installed CHP units to realize heat and electricity savings.

The great number of projects built to date has fostered local expertise in agricultural regions, but the simplicity of building an uncovered anaerobic lagoon has allowed many unexperienced consultants to enter the market as biogas technology suppliers. Despite the large number of failed projects, it has been shown that some agricultural biogas plants are profitable when good design and construction practices are followed, quality equipment is purchased, and expert advice is considered in operations.

Continuously Stirred Tank Reactors (CSTR): This type of digester is mainly used in WWTP for the stabilization of residual sludge, however there are a couple of cases in Mexico where CSTR digesters are used for food waste treatment. In WWTPs, the biogas generated is usually fed in CHP units where the produced electricity reduces the plant's energy demand, and the heat is transferred to the digesters for maintaining the optimal operation temperature. At least seven WWTP have been identified to not utilize the biogas produced in the CSTR reactor. In some cases, the sludge produced by the treatment plant does not meet the capacity of the digesters, providing an opportunity to the introduction of other types of waste in co-digestion for an increased biogas output. For example, an assessment of the Hermosillo municipal WWTP, which has a 25,000 m^3 volume installed in 2 CSTR digesters, showed that the plant has more than enough capacity to process the 8,000 ton/year of organic waste produced by a nearby industrial complex, and this could increase the plant's energy output by 10% (presentation by IB-Tech).

Dry Digesters

This is a preferred technology for treating the Organic Fraction of Municipal Solid Waste (OFMSW) given its low natural moisture content of around 70%. Given the high viscosity that results from the low moisture content in the digester fluid, the mechanical arms that are connected to the central shaft rotate in a very slow motion to obtain the mixing required by the anaerobic digestion process. This type of technology has not been installed in Mexico, however it can be a good technology choice once Municipal Solid Waste (MSW) Biogas Plants appear in Mexico.

Ultra-Dry Batch Digesters

This is another technology that can treat substrates with low moisture content, but its operational requirements are substantially different to that of the dry digester. SuKarne, a large meat production company installed a 4,500 ton/yr plant using german technology (Bekon) for the treatment of bovine manure. However, successful operations were not sustained for a long period of time, and this plant will now serve as an experimental site to co-digest the organic fraction of municipal solid waste (OFMSW) with the Riviera Maya sargassum. A pilot scale plant using ultra-dry batch digesters is under planning by researchers of the Universidad Autonoma Metropolitana (UAM) in Mexico City. They intend process the food waste from university cafeterias in co-digestion with grass cutting from the campus lawns.

Landfills

The least efficient way to produce biogas from organic waste is through landfills. Properly built landfills can be covered with an HDPE liner and biogas can be extracted through a piping network. From 1995 to 2012, the number of landfills in Mexico went from 30 to 260 a 15% increase (SEMARNAT 2012) (Figure 18). The first project to generate electricity from landfill biogas dates to 1991, a 20 kWe demonstrative plant in Santa Cruz Meyehualco, a landfill serving Mexico City. By 2015 only 8 landfills with a total installed capacity of 34 MW generated electricity from biogas (GIZ 2018). This means that there are at least 252 landfills in which biogas utilization projects can be implemented.

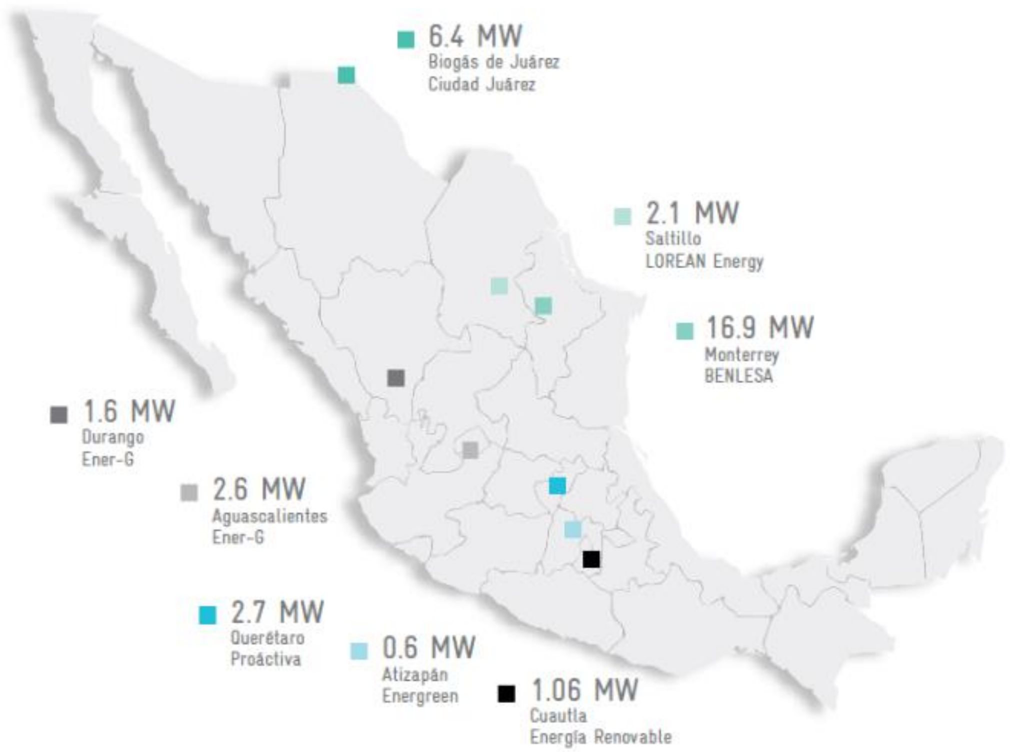


Figure 18: Distribution of biogas electricity-producing landfills in Mexico showing the private companies involved in each project. [Source: GIZ, 2018]

Biodiesel

The biodiesel production process is obtained through the transesterification of animal and vegetable oils, it is produced with a reaction of those oils, in combination with alcohol and in the presence of a catalyst to produce monoalkyl esters and glycerine (DOF, 2008). This biofuel can be classified according to the biomass used in the production, edible / food sources also called "First Generation" and those from inedible / food sources called Advanced Biodiesel (ASTM International, 2015).

Advanced Biodiesel

This biofuel is considered for the report, where the biomass used for production comes from animal and vegetable oils residues, from non-edible sources, and similar to diesel for its chemical structure and energy content (Advanced Biofuels USA, 2012).

Biodiesel is normally mixed with petroleum diesel, with B20 (20% biodiesel and 80% petroleum diesel) being the most common blend. Biodiesel can also be used in small proportions instead of lubricant additives to improve the lubricity of a highly desulphurized diesel fuel (Haupt et al., 2010).

Biodiesel from waste fats and oils: The potential for obtaining used cooking oils and animal fats for biodiesel in Mexico is uncertain since currently there are simultaneous uses for many of these sources of fats, and in many cases the capacity and disposition to pay concurrent users would be higher than the potential biodiesel users. This is the case of animal fats, for which there is a high demand for raw materials in soap making, food additives, pet food, and other uses. Even though used cooking oils have few alternative uses, some authors sustain that there is an informal collection circuit, with operators who filter, discolour, and bottle the recycled oil to sell it as edible oil (Figure 19).

However, the use of waste oils can present technical and logistical problems due to their residual nature such as their collection, control, and traceability. This feedstock may also require several processes for its conditioning when it has high contents of material, water, and free fatty acids. Hence, the production costs of biodiesel from waste oil may be high.

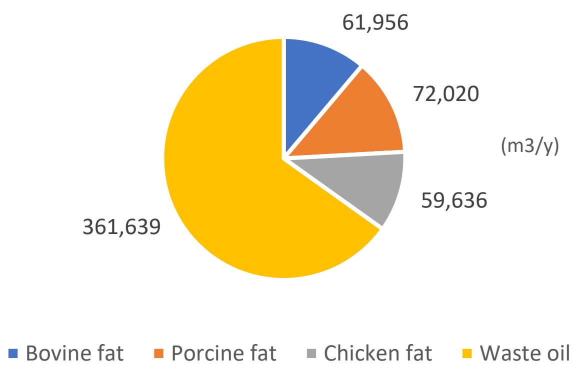


Figure 19. High Potential Scenario for obtaining used cooking oils and animal fats for biodiesel, [Source: REMBIO, data from SIAP and INEGI]

Mexico lacks mandates which set objectives to produce biodiesel or blending obligations (Energy Transition Law and projections elaborated by SENER). In contrast, Brazil and the European Union have a blending obligation of 8% and 5.75% respectively (USDA, 2015). The United States does not only have a blending mandate of 10%, but it also has annual production goals (EPA, 2016). Therefore, the experiences of countries like Brazil and the United States, and the European Union must be considered as a reference in the design of public policy instruments to promote the growth of the biodiesel market.

It is necessary for Mexico to develop standards that guarantee the quality of biodiesel and its commercialization such as UNE EN 14214 and ASTM D6 751, which specify the quality of biodiesel produced from vegetable oils, ASTM D7 467 which regulates the blend of biodiesel with diesel 6 at a 20%, and EN 590 which regulates the quality of gas oils and blends of up to a 5% biodiesel.

Table 19. Biodiesel commercial plants, Source: [SAGARPA, 2015]

Location	Capacity (m3/yr)	Input type	Opened
Puebla	90	Waste oil	2010
Puebla	959	Animal fat	2011
Baja California	74	Ricinus communis	2014
Durango	1440	Animal fat	2015
Mexico City	628	Animal fat	2015
Oaxaca	1000	Ricinus communis	2015

3.3.1.2. COMBUSTION

Municipal Solid Waste Incineration

In April 2017, the Mexico City government announced the concession of a 30-year design/build/operate contract to Proactiva Medio Ambiente, a consortium led by the French company Veolia. With a total investment of $550 million USD the plant was going to process 4,500 tons/day of unrecyclable MSW to be combusted and generate 965,000 MWh/yr; enough to power the Mexico City subway system.

In 2016, Mexico City paid a total of approximately $230 million USD for disposing 4,500 tons/day in State of Mexico Landfills, and $100 million USD for the electricity used by the subway system. In contrast, this project was going to cost $115 million USD/yr for operations and maintenance service provided by the winning consortium (Veolia, 2018). However, the new administration of the Mexico City government took office in December 2018, and soon after decided to stop this project before construction started. The project is currently under litigation between the Mexico City government and Proactiva Medio Ambiente. It may take years before an agreement is reached on the continuation or cancellation of this project.

Co-combustion

Combustion isolated or jointly with other fossil fuels is called co-combustion; which is the most common way to extract energy from biomass. These technologies are mature and available in Mexico however they require high investment costs. Examples of different systems: direct co-combustion, indirect co-combustion and parallel co-combustion.

Biomass

Fuels obtained from biomass from organic matter of agricultural, livestock, forestry, aquaculture, algaculture, fishing, domestic, commercial, industrial, microorganism, and enzyme activities, as well as their derivatives, produced by processes sustainable technologies that meet the specifications and quality standards established by the competent authority under the terms of the "LPDB".

In Mexico, the biomass that is mostly used to produce electric energy is the sugarcane bagasse, with notable increases in installed capacity and generation from 2005 to 2015 (See Figure 20).

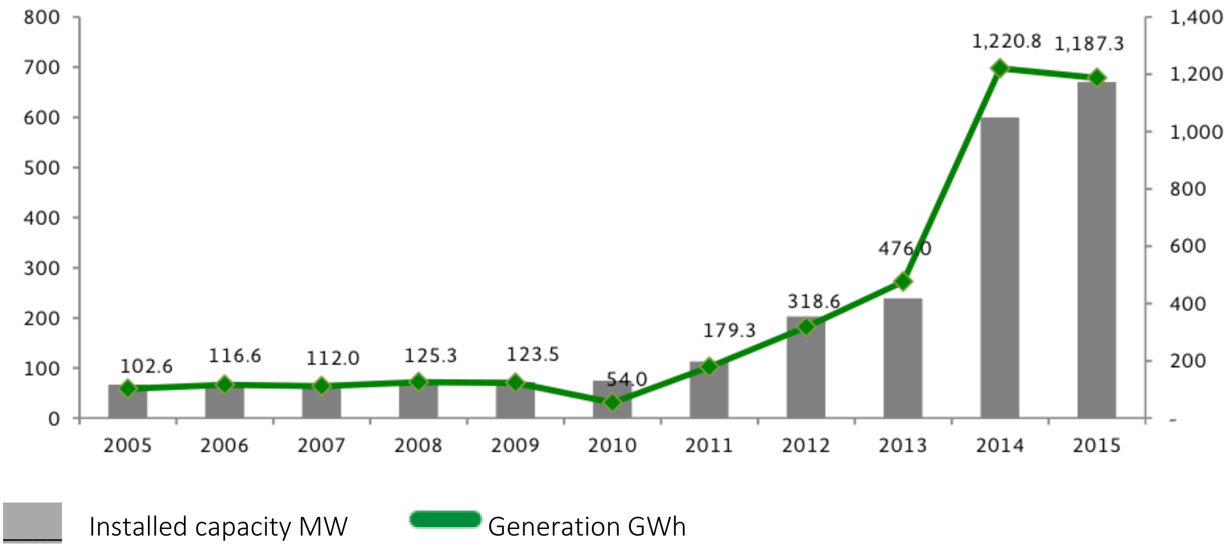


Figure 20, Installed capacity and electrical generation from sugarcane bagasse, 2005-2015 (MW,GWh); [Source: SENER, 2016]

Great efforts have been noted by the sugar industries in Mexico when carrying out projects that reduce the consumption of fossil fuels and occupy cogeneration (Figure 20):

- Sugarcane bagasse is used as a biofuel in 52 sugar mills to produce heat and electricity.
- In 2014 the installed capacity of electric generation was 184.2 MW with a generation of 438.6 GWh, for 2016 the installed capacity grew to 599.1 MW to generate 1187 GWh.
- The regions with the highest production of electricity through bioenergy are Eastern and Western, with 598.0 GWh and 389.0 GWh respectively.
- In 2015 in the Peninsular region with only one power plant generated 40.0 GWh and in the North region, with three plants whose combined capacity was 9.0 MW, generated 24.0 GWh.

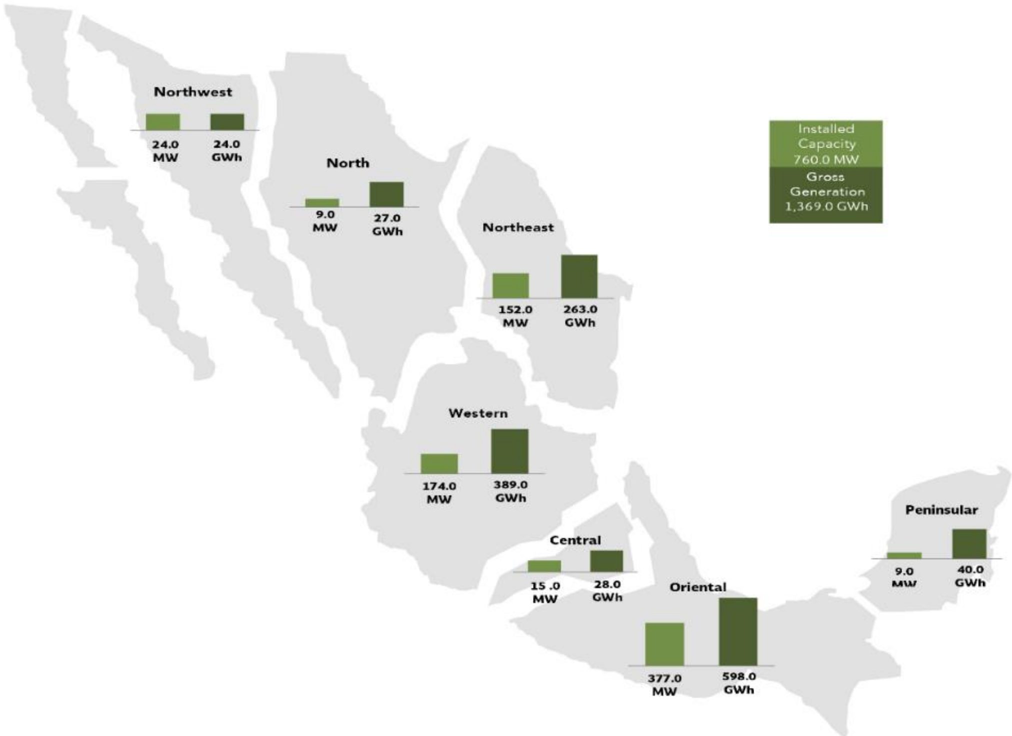


Figure 21, Bagasse capacity and generation of power electricity, 2015 (MW,GWh); [Source: SENER, 2016]

Solid biofuel processing

It can be used directly as a biofuel or include pre-treatment and densification, depending on the physical, chemical characteristics or improvements in logistics costs required for biomass.

Table 20: Processing technologies for solid biofuels; Source: [Shankar Tumuluru, et al. 2010]

Technology	Subprocess	Description	Final product
1. Direct	1.1 None	Incineration of sugarcane bagasse	Energy production
1. Direct	1.2 None	Incineration of sawdust and firewood	Energy production
2.Pre-treatment (previous process for the mechanical and thermal densification)	2.1 Grinding	Size reduction of biomass to influences the adhesion characteristics and mechanical properties of final products	Briquettes and pellets

2. Pre-treatment	2.2 Drying process	Reduce the density, increase calorific value and durability of the biomass	Same biomass without humidity
2. Pre-treatment	2.3 Agglutination	Influence biomass density and durability	Same biomass
3.Mechanical densification	3.1 Pelletized	Apply pressure to increase specific weight	Pellets with high energy density and low humidity
3.Mechanical densification	3.2 Briquetting	The biomass is heated and compresses with high pressure causing lignin to plasticize and adhere in the form of briquette or brick	Slow burning briquettes compared with pellets
4.Thermal densification	4.1 Extreme pyrolysis	Carbonization of wood with firewood in brick kilns	Charcoal
4.Thermal densification	4.2 Intermediate pyrolysis	Heating processes in inert atmospheres and at atmospheric pressure	Improved charcoal without moisture and volatile compounds

In Mexico, there are companies that produce solid biofuels. For example, in 2014, 700 thousand m^3r (cubic meter roll) were produced, from Durango, Sonora and Tamaulipas which were the States with the highest production and exporting more than half: 495 m^3r (SEMARNAT, 2014).

Table 21: Solid biofuel processing companies in Mexico; [Source: REMBIO]

Company	Biomass	Location
Maderas y Materiales San Mateo	Wood pellets	Durango, Durango
Comprimidos de Biomasa Todo Pellet	Pellets agricultural waste	Irapuato, Guanajuato
Noram México	Charcoal	Durango, Durango
Silvicola Tapalpa	Wood chips	Ciudad Guzman, Jalisco
Maderas Tarahumara	Chips, sawdust and charcoal	Guadalajara, Jalisco
Carboneros y Briqueteadores del Noreste	Charcoal and briquettes	Monterrey, Nuevo León

Use of solid biofuels

The use of solid biofuels is divided by the final objective, where commercial and industrial size systems "HPT" are destined for the generation of heat, electric energy or both (cogeneration) or mixed with fossil fuels (co-combustion) and those of residential size "LPT", they are usually used for use in stoves and boilers that occupy firewood, pellets or wood chips:

High power technologies ("HPT"): The use given to solid biofuels is to generate heat, electricity or cogeneration, where the most commercial systems are medium and large scale in Mexico, for example: grilling, fluidized bed combustion and pulverized combustion.

Low power technologies ("LPT"): Heat generation in residential and commercial use includes low power technologies, such as cooking stoves, boilers and heating stoves that use wood, pellets and wood chips. The use of pellet stoves for heating is still scarce, there is no great availability of technology in the domestic market and in the commercial sector the heating and heating of water continues to use fossil fuels, due to the low cost and high knowledge of technologies (Rosendahl, 2013).

3.3.2. MARKET OVERVIEW

3.3.2.1. MARKET SIZE

The global waste to energy market was valued at €15.5 billion in 2017, and is projected to reach $24.9 billion by 2025 (Yenduri and Sumant, 2018). Incineration is the most common waste-to-energy method employed worldwide. The Mexican Waste-to-Energy Sector offers a wide variety of business opportunities for project developers. Currently, the main areas of exploration in Mexico have relied on combustion of sugar cane bagasse (biomass) and anaerobic digestion to generate biogas, mostly focused on wastewater treatment plants as well as agricultural installations for self-supply. In 2015 there were 70 recognized biomass and biogas installations, and they provided a combined output of nearly 1,400 GWh in 2015. According to SENER, Mexico produced a total of 276 GWh of electricity from biowaste in 2016, which in today's average market prices would be the equivalent of 45.5 million Euro. The Ministry of Energy (SENER) has estimations of the following trends with respect to the increases in installed capacity and power generation potential:

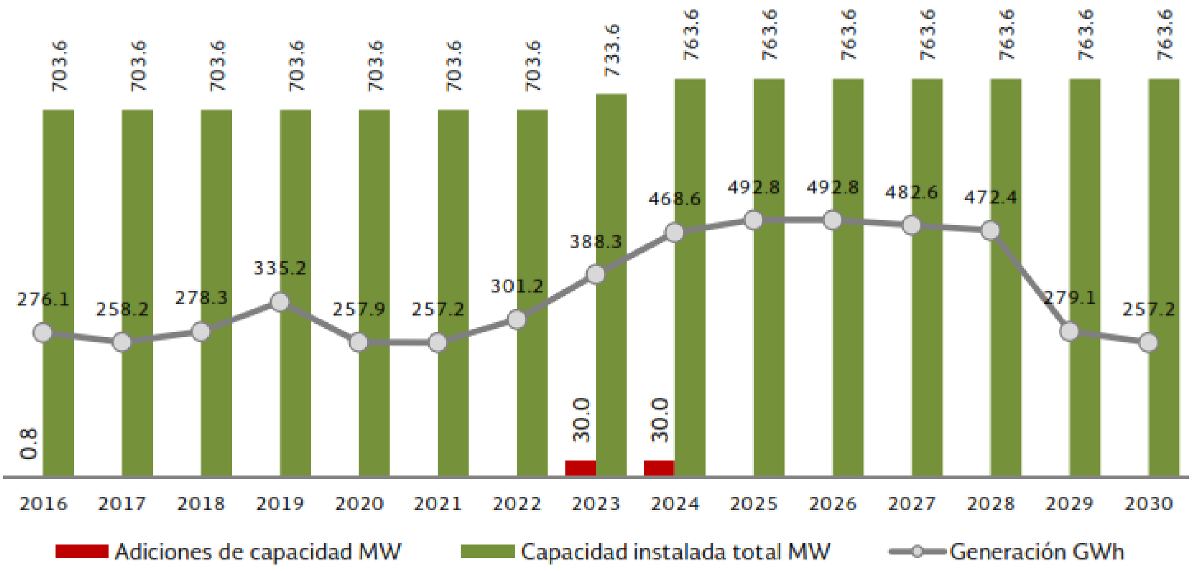


Figure 22: Expected Installed capacity and electrical generation from Bioenergy, 2016-2030 (MW,GWh); [Source: SENER, 2016]

In the wastewater treatment sector, the current waste to energy market is very small compared to its potential. For instance, of the 104 municipal WWTP with potential to generate biogas, only 16 have digesters. In addition, of the 16 municipal WWTP producing biogas only 9 are producing electricity. The energy potential in Mexican for municipal WWTP is 304 GWh/year from biogas produced electricity (IMTA-SENER, 2016). Assuming a price of 165€/MWh, the potential market size from generating biogas electricity in Mexican WWTPs is well over 50 M€ annually.

The level of future penetration of biodiesel in the fuel market in Mexico will depend on a great number of economic and technological factors, as well as political decisions. The development of future scenarios of biodiesel introduction in Mexico requires analysing several elements along the value chain of biofuels, from feedstock production to the commercialization in the fuel market, including infrastructures for the conversion of feedstocks into biofuel. An example of one possible scenario according to the Diagnostic on the Current Biodiesel Situation in Mexico, issued by SENER :

Optimistic scenario.

- Market share in 15 years: 6%.
- Average increase share volume: 160,000 m^3/year.
- Biodiesel infrastructure investment 2018-2036: from 12 to 18,000 million MXN (around €845 million).

Assumptions:

- Increase share based on European Union experience after 15 years.

- Needs constant and mandatory support from biodiesel regulations.
- Crude oil prices from 50 to 100 USD per barrel until 2025.

The following figure shows the evolution of biodiesel market share.

Figure 23, Biodiesel Mexican market share evolution (millions of m^3 and %); [Source: SENER, 2015]

Sales volume --*-- Market share (%)

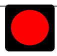
The volume of demand for diesel fuel assumes a low average annual growth, equivalent to 50% of the projected in the "Oil and Petroleum Prospects 2015-2029", a report by SENER.

3.3.2.2. MARKET NEEDS

By identifying the market needs, this section detects the main business opportunities in the Mexican Waste to Energy Sector. Table 22 gives an indication of the level of need of the Waste to Energy technologies in Mexico.

Table 22: Level of need for different WTE technologies.

Biogas Technology	Level of Need	Description
Upflow Anaerobic Sludge Blanket (UASB)		It has an adoption rate of more than 10%, and it has proven to be an OPEX reducing technology
Expanded Granular Sludge Bed (EGSB)		The industrial sector will be attracted to this technology due to its high efficiency and compactness
Anaerobic Lagoon (AL)		The technology of choice by the agricultural sector for manure treatment. Upgrades in the grit removal pre-treatment and mixing systems will improve its acceptance and expansion
Continuously Stirred Tank Reactors (CSTR)		The 30 CSTRs installed in the Atotonilco MWWTP will increase the awareness of this technology

Dry Digesters		Expected to appear once MSW Biogas Plants start to be built in Mexico
Ultra-Dry Batch Digesters		The experimental results that derive from the SuKarne plant will be key for the success of this technology in the near-future
Landfills		The trending disposal method for MSW, however very few cases in which biogas is recovered for energy
Biodiesel Technology	Level of Need	Description
Advanced Biodiesel		The technology is currently strengthening the biomass collection to ensure better and continuous production
Combustion Technology	Level of Need	Description
Pelletization		For heating use in houses in rural regions in Mexico
High Power Technologies		The most common use in México is with sugarcane bagasse as a biofuel to produce heat and electricity
Low Power Technologies		In 2014, 700 thousand m^3r (cubic meter roll) were produced, with the highest production and exporting more than half: 495 m^3r

3.3.2.3. WASTEWATER TREATMENT

CSTR Reactors: Most wastewater treatment plants do not treat the residual sludge in anaerobic digesters; thus, missing an opportunity to cut down on operational costs by generating electricity from biogas. In addition, some biogas plants that have digesters for sludge treatment, only burn the biogas without energy utilization. This latter case represents a relatively simple, low investment, and potentially high return project to execute. The IMTA-SENER 2016 report identifies the biogas energy potential at 104 MWWTP that have a minimum flow rate of 200 L/s where installing a sludge digester might be a viable option.

- UASB/EGSB Reactors: The introduction of anaerobic treatment prior to the aerated biological reactors in MWWTP can carry significant operational cost reductions. This can be demonstrated in design proposals and/or feasibility studies, to begin with.
- UASB/EGSB Reactors: The tequila industry could benefit from installing these technologies to treat vinasse and generate biogas for internal thermal processes. Of the 250 ML of tequila produced in 2017, 50% was produced by large companies exclusively located in the state of Jalisco. Of the 3.8 Mm^3 of produced vinasse only 13% was treated, and there's a thermal energy potential of 600 TJ/yr if 50% treatment is reached (REMBIO, 2018).
- UASB/EGSB Reactors: Corn milling companies with distribution capacity can employ this technology to treat the liquid residue (nejayote) resulting from the tortilla flour making process. These companies have the investment capacity to produce biomethane for powering their distribution fleet as well as their process, itself. Of the 2.5 Mtons of corn flour produced in 2015, 90% was produced by 2 companies: Gruma and Minsa. Only 5% of the 7.5 Mt/yr of produced

nejayote is treated, this represents a biogas thermal energy potential of 1PJ/yr if 50% treatment is reached (REMBIO, 2018).

- Co-digestion: It is common for sludge treatment digesters to be overly-dimensioned in Mexican industrial installations. This represents an opportunity to generate value to the business model through the incorporation or increase of electricity production, by introducing nearby generated organic waste in the oversized digesters in retrofits, or including them from the very design of the industrial installations.
- Biomass Combustion: There are no cases in Mexico where the combustion potential of dehydrated sludge is utilized. Landfills are still a preferred method of disposal for dehydrated residual sludge, mainly due to lack of experienced service providers rather than other market barriers.

3.3.2.4. AGRICULTURAL SOLID WASTE

- Improved AL or CSTR: Vertically integrated meat and dairy companies are well structured companies that produce a wide range of substrates and can utilize biogas for thermal, electricity and transportation purposes. In addition, they can utilize digestate to enhance forage crop fields, since they grow their own. These companies are characterized by their high investment capacity.
- Improved AL or CSTR: Large scale meat and dairy Farmers are fully aware of the potential of biogas technology given that there are over 1,500 digesters installed in this type of farm. However, most of these plants are poorly designed and operated. Key technological and operational improvements can make these projects financially attractive for farmers with access to financing and government subsidies.
- Biomass Combustion: Solid biofuels have an energetic potential of 472 PJ/year from agricultural residues and 125 PJ/year from agroindustry residues. The combined use of wood chips with residues of sugar cane in sugar mills (bagasse and straw) has an estimated cogeneration capacity of 900 MWh. Sugarcane bagasse, corncobs, olotes, maguey bagasse, rice and peanut husk, and coffee pulp among others have an estimated generation potential of between 100 and 125 PJ/year.

- Biomass Combustion: The agave bagasse can be properly treated for harvesting its combustion potential. The thermal energy demand in the Tequila industry comes from agave cooking and distillation traditionally using LPG and fuel oil. There’s a recent move towards CNG and bagasse furnaces. A tequila distillery can supply 60% of its thermal energy demand form bagasse combustion, 20% from vinasse biogas and 20% from CNG (REMBIO, 2018). Large scale distilleries have high investment capacity.

3.3.2.5. MUNICIPAL SOLID WASTE

- Biogas or Incineration Plants: The gas biofuel potential from MSW is estimated at 495 PJ/year. There are no large biogas or incineration plants to treat MSW in Mexico, while there are 36 Municipalities with a population over 500,000 which generate enough waste to build a cost-effective waste to energy plant. Momentum is building for a 400 ton/day of OFMSW biogas plant in the Municipality of Naucalpan, State of Mexico that is being backed up with feasibility studies funded by US-EPA and GIZ.

- **CHP Units**: By 2015 only 8 landfills with a total installed capacity of 34 MW generated electricity from biogas (GIZ 2018). This means that there are at least 252 landfills in which biogas utilization projects can be implemented.
- PPP structures have been successfully used in health and education infrastructure projects, there is a clear opportunity to explore such partnerships

3.3.2.6. WASTE HEAT RECOVERY AND COGENERATION

- In a 2017 study, SENER reported a market size considering industrial sectors with demands greater than 1,000 kW and load factors greater than 50%, as well as the particular case of sugar mills and PEMEX. The study estimates that the maximum national potential of cogeneration, economically feasible with surpluses to the National Electric System (SEN), is 10,164 MW and is distributed as follows:

Table 23: Cogeneration capacity in Mexico. [Source: SENER-GIZ, 2017]

Sector	Theoretical Maximum (MW)	Technically Feasible (MW)	Financially Feasible (MW)	Maximum Potential with Industrial Excess Capacity (MW)
Industrial	2,630	2,286	1,989	6,085
Sugar	979	979	979	979
PEMEX	3,100	3,100	3,100	3,100
TOTAL	6,710	6,365	6,069	10,164

- The study also establishes that it is not possible to develop all the identified cogeneration potential in the short and medium term due to market and regulatory inefficiencies
- In this way, it was estimated that the national potential of cogeneration that could be developed in Mexico varies from a minimum of 849 MW to a maximum of 8,457 MW for the sectors studied.

3.3.2.7. OTHER ASPECTS

- Performance-based contracts seem like a promising instrument to establish an impactful presence in the W2E market in Mexico, especially given the lack of enthusiasm for such projects from the local community thus far.
- Small and Medium-Sized Enterprises have begun being audited to meet the evermore stringent requisites that their buyers are actively pursuing up to the 3rd and 4th tier (apparel, food, electronics, and other multibillion-dollar market maquiladoras and exporters).

3.3.3. CONCLUSIONS AND RECOMMENDATIONS

In recent years, Mexico has seen the emergence of many successful waste to energy projects. For example: the agricultural biogas plants, digesters for treating sludge in MWWTP, electricity generation from bagasse combustion in sugar mills and biodiesel from waste fat plants. Although these efforts still account for a very small fraction of the waste to energy potential in the country, it sets a base of potential local partners (both private and public) with experience and vision of a more mature waste to energy industry in Mexico. The inclusion of international state-of-the-art technologies and know-how will be key for a bright future in the Mexican Waste to Energy Sector. This section summarizes the relevant ideas to consider when looking for waste to energy business opportunities in Mexico.

- The Municipal Wastewater Treatment sector offers business opportunities in both biogas and combustion technologies. Starting with the 7 Municipal WWTP that produced biogas from sludge treatment but are currently not recovering energy from it. Furthermore there are 104 Municipal WWTP that generate enough sludge volume to justify the investment in a CSTR reactor for biogas production. Besides, the over-sized sludge digesters present an opportunity to increase efficiency by using nearby organic residues in co-digestion. Finally, there's no record of a WWTP that is sending its dried sludge to industrial facilities to be used in co-combustion processes.
- The confirmation of the new wastewater discharge regulation (PROY-NOM-001-SEMARNAT-2017) can open the gates for the increased demand of UASB and EGSB reactors for WWTP retrofits.
- The tequila, corn milling, meat, and dairy sectors have very large companies that generate energy-rich residues with both biogas and combustion potential that's not being exploited.
- There are at least 252 landfills in which biogas utilization projects are not being implemented.
- The actions being taken by the Danish Energy Agency will facilitate the rapid assessment of biogas projects based on both technical and financial data on local market dynamics like higher cost of capital, lower tipping fees and a high degree of informality imply a relatively high barrier of entry. Waste to Energy projects can quickly assist Mexico in meeting the ambitious GHG emission reduction targets signed in Paris.
- Real Estate Investment Trusts (or FIBRAS for their Spanish initials) have become a popular instrument in Mexico that offer a good opportunity to explore that could bring multiple industrial opportunities through a single channel.

4. ENTRY PHASE AND FINANCIAL INSTRUMENTS AVAILABLE

With an understanding of the market, the opportunities that each of the sectors presents and the barriers to those opportunities, this section gives insight into how European and Mexican business can enter business together, through the funding mechanisms available and the programmes focused on circular economy in Mexico.

4.1. NATIONAL FUNDING AND PROGRAMMES

The processes to access government programs vary depending on the type of support you want to obtain, since the established requirements differ. The deadlines are also different, depending on whether the person who wants to operate the project has the permits or is going to start the process.

However, there are certain steps and aspects that an organization looking to doing business within circular economy in Mexico would need to consider:

- ✓ Firstly, identify the need for financing: the municipality or agent must clearly identify what is the need to be financed in the circular economy process. Principally support requests are concentrated on equipment and infrastructure for the collection and separation of waste.
- ✓ The need for financing: An organization looking to do business in Mexico should have prepared the good for which the support is requested will be used, its operating characteristics, estimated costs and operating mechanisms; for example, if it is a team, the minimum volume required for it to operate, the training requirements for the type of technology, energy requirements etc.
- ✓ Accreditation of the property or the area where the works will be carried out: the property title must be accounted for, failing that, a legal document certifying the ownership of the place where the project is to be established or the property.
- ✓ Accreditation of current regulations: in the case of buildings, there must be an Environmental Impact Evaluation (preventive or hazardous waste management).
- ✓ Preparation of an economic study for the project. This study must contain information that shows that the project is economically viable and that the investment (support) requested allows sustainable flows over time
- ✓ Processing permits with the CRE: for projects that intend to cogenerate, self-supply or sell energy, a permit must be processed before the Energy Regulatory Commission (they may take a year from the moment they are requested until the resolution).
- ✓ Bidding process of the project: when it comes to public procurement, the applicant (municipality or state) is required to bid for the required service, which may be in the form of invitation or public, depending on the amount required. Times vary, depending on the procurement legislation established by each state or municipality.
- ✓ Reports (notice of completion of the work and closure of the project): during project financing processes it is common to request progress reports, as well as the notice of completion of the work and closure of the project with which it is carried out

Program for the Prevention and Integral Management of Waste-SEMARNAT

Objective: to promote the integrated management of solid urban waste and special waste in Mexico, through the financing of studies or programs for the prevention and integral management and projects to increase the installed capacity for the collection, use and adequate disposal of said waste.

Program of Environmental Strengthening of the Federative Entities-SEMARNAT

Objective: to contribute to the accomplishment of the goals related to the care of the environment and those linked to sustainable development and green growth as a fundamental purpose of the governments including integral waste management, environmental education, adaptation and mitigation of the effects of climate change, as well as the reduction of greenhouse gases, and the use of clean energy.

Fund for the Energy Transition and the Sustainable Use of Energy -FOTEASE- SENER

This Fund does not constitute a program of direct subsidies but contributes to finance programs and projects focused on the following aspects: use and application of technologies for the use of renewable and clean energy; promotion of energy efficiency and energy saving in different sectors: residential, industrial, commercial, agricultural, among others.

Objective: to finance programs and projects focused on the following aspects:

a) Use and application of technologies for the use of renewable and clean energy.
b) Promotion of energy efficiency and energy saving in the different sectors (residential, industrial, commercial, agricultural, among others).
c) Diversification of energy sources to carry out the energy transition in Mexico. d) Collection, generation and diffusion of renewable and clean energy potential in Mexico.

HABITAT-SEDATU

Promotes and encourages works and actions (for example studies) that contribute to the sustainability, conservation and improvement of the environment that imply the use of new technologies, that allow to apply systems or devices of high energy efficiency, the recycling of materials, savings or a better use of energy and water, among others.

Objective: to contribute to productive, competitive, inclusive and sustainable cities, which facilitate mobility and raise the quality of life of its inhabitants by supporting strategies for the realization of integral works of basic and complementary infrastructure that promote connectivity and accessibility; as well as the provision of Community Development Centres where courses and workshops are offered that address the integrity of the individual and the community.

Wastewater Treatment Program (PROTAR) -Conagua

Strengthens sanitation actions through the treatment of larger volumes of municipal wastewater, with the purpose of reducing, preventing and / or controlling the contamination of the national water bodies and supporting the water operators to comply with current regulations; in addition, it contributes to improve the environmental and ecological status of the water bodies. PROTAR can finance projects for the use of energy for wastewater.

Objective: to assign federal resources to the water operators, to design, build, expand, or rehabilitate wastewater treatment plants, and thus increase the volume treated or to improve their treatment processes.

4.2. INTERNATIONAL FUNDING AND PROGRAMMES

This section includes a list of the relevant funding programmes or initiatives that from an international stand point are supporting investments of European organizations in Mexico.

France: Le Comité pour les Métaux Stratégiques (**COMES**) seeks to strengthen the security of supply of strategic metals. Its activities include work on specific recycling targets for strategic metals as part of certain extended producer responsibility (EPR) schemes. The French agency ADEME also commissioned and published a study on research and development priorities for the recycling of critical metals with a focus on Mexico.

The Netherlands: A Government-wide Programme for a Circular Economy addresses critical mineral raw materials by promoting their substitution, efficient use, re-use and recycling. The Ministry of Economic Affairs has also commissioned the development of a "resource scanner", a method and IT tool to map out business risks.

H2020: Through the Horizon 2020 programme, the Commission is co-funding ERA-MIN 2 which is the largest network of R&I funding organisations in the mineral resources field. It is a public-public partnership of 21 research funding organisations from 11 Member States, two regions and five non-EU countries. In February 2017, a joint call, "Raw materials for the sustainable development and the circular economy", was published, including a topic on design of products: efficient use or substitution of critical materials in products and components, product durability, facilitation of recycling with a focus on Mexico. There are two main call areas that focus on the circular economy and have Mexico as a priority in the circular economy:

- Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement"
- "Greening the economy in line with the Sustainable Development Goals (SDGs)"

Global Environmental Facility (GEF), managed through the UNDP, UNEP, WB, UNIDO, African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, IDB, and IFAD. It finances projects through donations or concessions. Any person or group can access it and it finances project in the areas or climate change and environment. Mexico has 48 published projects, 16 of which are in climate change (http://www.thegef.org/gef/gef_country_prg/MX).

World Bank (WB) manages two Climate Investment Funds: Clean Technology Fund and Strategic Climate Fund. Additionally, the IFI the affiliated World Bank institution directed to the private sector, has come associated funds: Clean Technology Fund, Strategic Climate Fund, Carbon Alliances Fund, Forest Carbon Partnership Facility and Support to the Development of Green Infrastructure. In Mexico this adds us to USD 500 million authorized for projects that include energy efficiency and emissions reduction.

Inter-American Development Bank (IDB). The IDB group is made up of the Inter-American Development Bank (IDB), the Inter-American Investment Corporation (IIC), and the Multilateral Investment Fund (MIF). The IIC supports mainly SMEs and the MIF promotes the growth of the private sector through donations and funding, with emphasis on micro enterprises. One quarter of the annual IDB loans for

2015 (almost USD 3.000 million) is directed to projects in the areas of climate change, energies, renewables and environmental sustainability. The action lines for the IDB to combat climate change are:

North American Development Bank (NADBANK) established the Border Environment Infrastructure Fund (BEIF) to manage the non-refundable resources given by the Agency for Environmental Protection of the United States with the objective to finance the construction of municipality works to water, sewage and water treatment in the border region between Mexico and the US. It only considers this type of projects within a 100 Km strip to both sides of the border.

UK Prosperity Fund –Under this fund, annual call for bids are launched each year, under the modality of grants. Prioritized areas include: support the implementation of the General Law on Climate Change Waste Management and Recycling Green Funds: Channelling of private and/or public funding for implementation of low carbon policies, Development of Green Banks, Renewable Finances

USAID – MLED. The MLED Program provides technical assistance to the Government of Mexico along 4 different efforts: 1. Design and implementation of a nationwide low-carbon development strategy, and action plans against climate change at the state level; 2. Systems strengthening for measuring, reporting and verification of greenhouse gas (GHG) emissions in Mexico, 3. Implementation of demonstration projects harnessing clean energy, 4. Coordination of the Global Climate Change (GCC) USAID/Mexico, 5. Promotion of financial analysis schemes for clean energy projects. The MLED launches annual calls for grants to NGOs, academic and private sectors.

MEXICO Sustainable Energy Technologies Development for Climate Change, (funded by the World Bank), which includes grants to private sector enterprises for (a) proof-of-concept stage development of ACE (Advanced Clean Energy) technologies and (b) collaborative clean energy commercialization (CCEC) targeting industry-academia collaboration for ACE technologies

European Investment Bank (EIB), Support to the direct foreign investment of the EU in Latin America. Support to projects that include improvements for environment, including renewable energies, and energy security from the EU. It finances projects up to EUR 5 million when it represents only up to 50% of the total amount.

5. CONCLUSIONS

Europe is the recognised global leader in the Circular Economy paradigm shift. Over the last few years, a shift in legislation, reform, initiatives and public acceptance has placed Europe firmly as the global authority in Circular Economy.

In stark contrast, Mexico, now the world's 11th largest economy, is producing significant waste production in a linear economy, accounting for more than 44 million tons per year (0.86 Kg per person), this number is expected to reach 65 million by 2030[32]. Furthermore, approximately only 9.6% of the solid waste generated in Mexico's cities is recycled each year (SEMARNAT, 2010), where 70% of that urban solid waste ends up in landfills (INEGI, 2016). With regards to food waste it is estimated that 34.5% of the country's total food production is wasted. This wasted food would be enough to feed 7.4 million Mexicans (World Bank, 2017).

It is within this solid waste management sector that two main areas of opportunities exist, namely: Municipal Solid Waste and Special Handling Waste. It is estimated that bringing the Mexican solid waste market to a more circular economy has a potential worth of 1,172 Million Euro per year. In terms of the Special Handling Waste, for instance the electronic waste represents a potential of 1 billion Euro market value that could be recovered each year through introducing circular solutions. Furthermore, the increasing building materials recycling and reuse activities will require an investment of up to 180 Million Euro per year to scale up the number of CDW recovery plants in the main 10 cities in Mexico.

Through introducing circular solutions Mexico's performance on the progress of SDG Goal 12 (responsible production and consumption) should improve from its current position of 74,2% of the way to completing all indicators within this SDG.

However, to keep pace with the significant consumption and production in Mexico, the water sector demonstrates significant water stress mainly related to climate, demography and industrial volume use. The level of water stress is an indicator for improved water management, wastewater treatment and reuse technologies. The problems related to urban wastewater are further compounded by the lack of maintenance of the urban wastewater treatment technologies. As a reference, 555 wastewater treatment plants (19.2% of a total of 2892 plants) were out of operation in 2015 (Conagua, 2014). Furthermore, the technologies used in urban wastewater treatment plants that are in operation in Mexico are antiquated.

The wastewater treatment sector has a potential market opportunity size for circular solutions of around 1644 million Euro for CAPEX related investment in wastewater treatment. Most of this increase is related to wastewater networks, whereas an increase in sludge management is lower in absolute values and capex is approximately constant for wastewater treatment plants. Operational expenses also show a steady increasing trend with the opportunities more significant for industrial uses (20.6%, from 1035.3€ million to 1249.2€ million) than for wastewater utilities (8.3%, from 731.8€ million to 792.3€ million).

Indeed, it is within the wastewater treatment sector that significant opportunities arise for waste to energy production in both biogas and combustion technologies. However, to date, there's no record of

[32] https://www.gob.mx/cms/uploads/attachment/file/435917/Vision_Nacional_Cero_Residuos_6_FEB_2019.pdf

a WWTP that is sending its dried sludge to industrial facilities to be used in co-combustion processes. The waste to energy sector needs to take advantage of these opportunities as the Energy Transition Law (LTE) states that 25% of the energy generated must come from clean energy sources by 2018, 30% by 2020, and 35% by 2024, therefore significant changes need to take place for this to be achieved. The unique production sectors of tequila, corn milling, meat, and dairy sectors generate energy-rich residues with both biogas and combustion potential that can be exploited. Biodiesel is also a potentially large market for circular solutions in Mexico, where it is estimated that biodiesel infrastructure investment from 2018 to 2036 can result in a market opportunity of 845 Million Euro.

Through collaboration, mirroring initiatives and following lighthouse case studies (specifically from the private sector), both Mexican and European entities can benefit in moving Mexico to a more circular economy. Herein lies a significant opportunity for investment and improvement in moving these sectors towards a circular economy.

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ANNEXES

Annex I: Solid Waste Management Sector Trends, Legislation, Policy and the Enabling Environment.

6.1.1. Sector Technologies and Trends

The First Industrial Revolution used water and steam power to mechanize production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres (Schwab, 2015).

Artificial Intelligence, Robots, Drones, Driverless trucks, 3D Printers, Internet of Things and The Revolution of Sensors, Decentralized Energy, DNA Engineering and the Rise of Bio-economy create a new landscape that will reshape manufacturing. It will also reshape waste management and recycling too, redefining the meaning of "waste", creating new technologies, delivering robotic solutions and driverless collection patterns (ISWA, 2017).

Following are some technological trends collected by (ISWA, 2017) during its annual congress in Baltimore, USA. They are related to the fourth revolution in the waste management sector:

- Driverless waste vehicles

The scarcity and safety considerations of the receiving vehicle drivers are two factors that will create conditions for unmanned vehicles to enter the waste management industry. Since waste collection and transportation is a very complicated task, it is highly probable that unmanned vehicles will be used first in other industries, but the unmanned transportation vehicles will still be the trend of the industry. Currently, manufacturers have tested unmanned garbage trucks in urban environments. For the sake of production safety, even if driverless driving is not fully realized, garbage trucks with collision avoidance function and automatic braking function are increasingly favoured by the industry (Zhang, 2018).

Volvo Group, together with Swedish waste and recycling firm Renova, is testing an autonomous refuse truck that the companies say has the potential to be used in urban settings. The project explores how automation can contribute to enhanced traffic safety, improved working conditions and lower environmental impact (Waste 360, 2017).

Figure 24 Autonomous Refuse Truck by Volvo

Source: (Volvo, 2017)

The autonomous truck currently being tested is fitted with a sensor system for identification, navigation, and monitoring of the vehicle's vicinity. Most of this technology is also used in the autonomous truck for mining operations that Volvo Group unveiled in 2016. That self-driving truck is undergoing tests in the Kristineberg Mine in northern Sweden (Volvo, 2017).

- Commercial robots for sorting recyclables from mixed waste stream

Robotic technology promises to significantly increase the sorting efficiency of some waste streams and could be particularly valuable in waste streams containing hazardous materials, as it could enable fine sorting without human intervention. Typically, a conveyor belt feeds the waste past a package of sensors including visible spectrum cameras, NIR spectroscopic cameras, 3D laser scanners and metal sensors, while robotic arms operate above the conveyor belt, removing materials as the waste moves past underneath (McKinnon, Fazakerley, & Hultermans, 2017).

Companies including Europe-based TOMRA Sorting Recycling; Eugene, Oregon-based Bulk Handling Systems (BHS); Canada-based Machinex; and Finland-based ZenRobotics are among those focusing on tying machine learning into devices and systems to offer thorough automated sorting options for recyclers (Taylor, 2019).

Figure 25 Sorting robot: Recycler by ZenRobotics

Source: (Taylor, 2019)

Companies such as BHS with its MaxAI systems, Machinex with its SamurAI line of sorting machinery and ZenRobotics with its Recycler have all gained attention and investments from recycling plant operators who have calculated that such advanced technology will yield a healthy return on investment (ROI) (Taylor, 2019).

- Several platforms and mobile apps for recycling systems, including platforms for informal recyclers

Undoubtedly, "The future is mobile". Nowadays, digital evolution and mobile developments are carving a new era that affects human behaviour and global governance. Interconnectivity and information flow through various types of modern means create new opportunities for cooperation and ways to work. Waste management could not stay unaffected by these changes. New potentials are arising for the sector, offering a novel field for innovation, changing the way waste practices are applied. In this framework, mobile products and applications (further apps) can become valuable tools for authorities, companies, civilians and other stakeholders, integrating these technologies in the battle for environmental protection, waste prevention, recycling, etc. (Mavropoulus, Anthouli, & Tsakona, 2013).

One example of this is Earth 911, which is an organization determined to spread the word about the benefit of recycling waste, launched the iRecycle app. The app helps users locate the nearest recycle centres in their vicinity. iRecycle is the premiere application for finding (United States Only), convenient recycling opportunities when you are on the go or at home. iRecycle provides access to more than 1,600,000 ways to recycle over 350 materials in the United States[33].

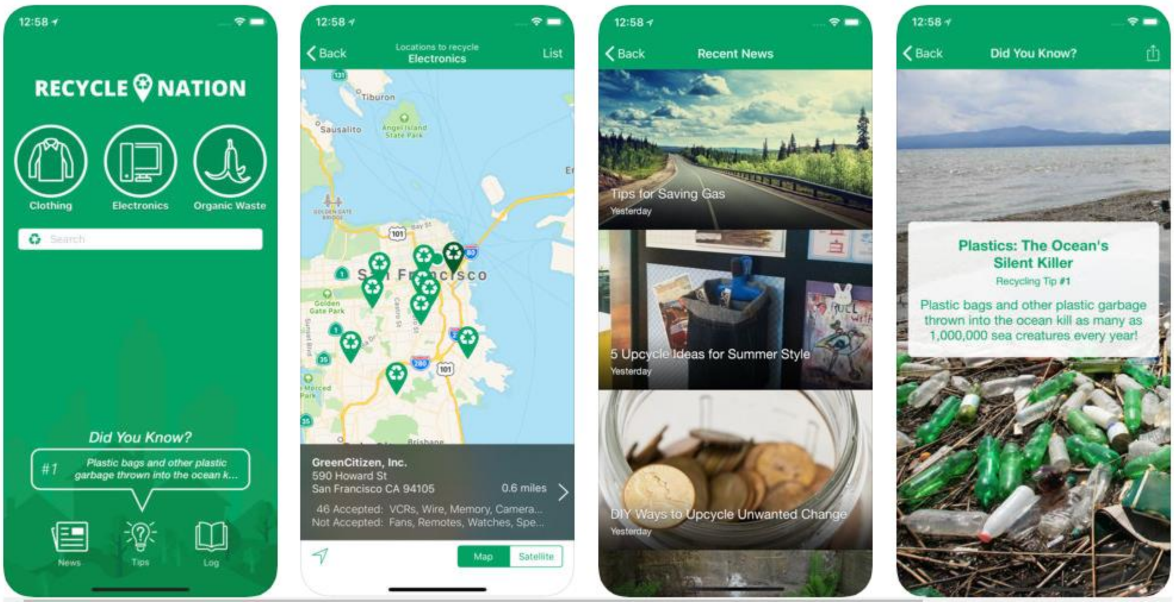

Figure 26 RecycleNation by Electronic Recyclers International, Inc.

Source: (RecycleNation, 2019)

Mobile phones can act as devices that connect different stakeholders. Through them, a municipal authority can spread information about its new campaign, introduce mobile applications that can help workers in the recycling sector acquire significant information and get organized. Residents from their side can find information on how to recycle different streams, organize their recycling efforts in cooperation with the municipality, send texts, pictures, comments, complaints, share special information with formal recycling schemes, as well as scientists, regarding their recycling handling, habits, quantities etc. In addition, people can get influenced and change their recycling habits. More specifically, they can participate in social media discussions, and be a part of pro environmental and recycling groups that promote sustainable living and recycling culture. From their side, children and

[33] https://earth911.com/irecycle/

students can change their behaviour by playing special games on mobiles, internet and tablets (Mavropoulus, Anthouli, & Tsakona, 2013).

- 3D printers used for the management of recyclable plastics

3D printing with pellets provides an alternative way to develop objects instead of reverting to plastic filaments. Due to the lower cost, individuals are able to print with higher-quality materials for the same price as a filament counterpart. However, small, low-cost machines are available that allow for local production of 3D printing filament from pellets or recycling at a reasonable cost (Goulding, 2018).

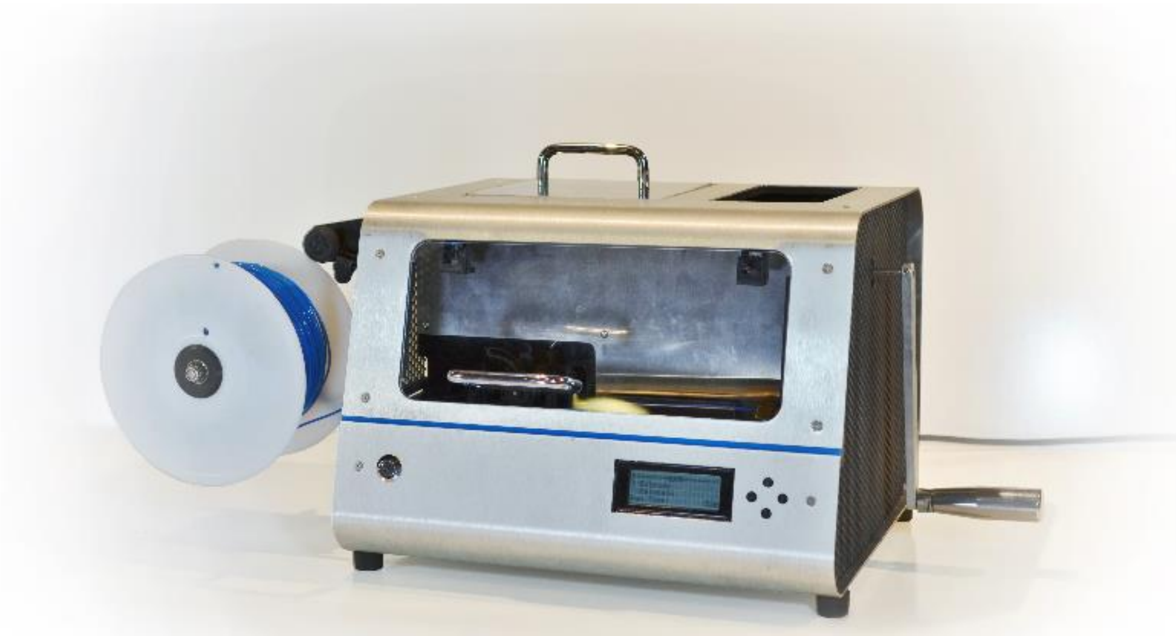

Figure 27 3D Printer ProtoCycler

Source: (O'Neal, 2014)

Engineering students at the University of British Columbia in Canada created the Protocycler which takes plastic water bottles and recycles them back to usable form. In addition, the Filabot is another filament extruder that has been on the market since 2013. These extruders grind the pieces, melt them down, and extrude the plastic filament on a spool. This provides an opportunity for individuals to easily recycle their plastic waste. Instead of throwing out your food container, you can put your plastic waste in the extruder and then make your own plastic spool that you can later print with again. Printing from recycled materials with Protocycler or the Filabot provide an estimated 90% cost savings on every spool that is printed (O'Neal, 2014).

- Internet of Bins (the incorporation of advanced sensors in waste bins)
- Internet of Garbage Trucks

- Internet of Packaging is gradually considered a cornerstone of the shift towards a sustainable management of packaging recyclables.
- Turning food waste to proteins that are used to feed animals
- Chatbots dealing with waste management and recycling

The on-going industrial revolution represents a potential for substantial benefits in recycling and waste management, because with the new cheap and energy efficient sensors, many industries will have the possibility to follow closely all the life cycle of any item sold. This will allow product designers to optimize the design, minimize useless functions and materials, prevent damages, improve maintenance, and finally develop closed loops of clean materials. "Zero waste" approaches for specific supply chains will become more realistic than ever. Reuse, recycling and material recovery will become easier, from a technological point of view (ISWA, 2017).

Management

Information on the generation and collection of municipal solid waste is generally available, but there are difficulties to integrate data between national and local levels, as well as between countries; this is due to the lack of harmonization of waste generation and management indicators.

Formal information systems are increasing in cities but they are not universal. For example, in Quito, Ecuador, La Empresa Metropolitana de Aseo (the Metropolitan Cleaning Company) has developed a central data management system that tracks collection routes, generates reports on service performance metrics, and allows citizens to report infractions of waste regulations. In Japan, a central data system connects waste facilities around the country to a central national waste information system. Measurements of toxins and emissions are reported in real time to the central database. Any problems in equipment operations trigger automatic reports to the plant operator so that emergencies can be addressed immediately (World Bank Group, 2018).

Therefore there is an an opportunity to upgrade the data management systems of Municipal Solid Waste in Mexico in the public and private sector. The most important waste management operator in Mexico is Promotora Ambiental (PASA).

Further information:

https://www.pasa.mx/

Storage, handling and collection

Waste collection and associated transportation is often the costliest step in waste management, and technology is extensively available to increase efficiency. Starting with the use of a geographic information system, a city can optimize routing and minimize improper use of trucks.

Sensors can optimize routes and reduce unnecessary pickups. Dumpster sensors can signal how full a dumpster is so that pickups can be made accordingly. Smart and solar-powered compactor bins use solar power to compact waste to one-sixth of its original volume and can alert the municipality or waste collector when a sensor detects that the bin is reaching capacity. In locations with sufficient infrastructure, relevant geographical conditions, and ample financing, alternative approaches are being used for waste collection.

Automation for waste collection vehicles ranges from the lifting of bins placed in the back of the truck to mechanical side arms that automatically pick up standardized bins directly from households.

These kinds of containers are equipped with coupling systems to be self-feeding by small containers and then lifted by special forks trucks or roll-off trucks. The trend is to get the container smarter fitting it up with sensors of quantity and quality of the content to process this information in a software and optimizing the collection system. It can be included the eco-points that promote the recycling culture through giving an incentive in exchange of specific materials.

Even more automated collection solutions are being tested. In a limited number of areas with restricted transportation access or that are extremely dense, a more unusual approach could be pneumatic waste collection.

Sorting and recovery

There are some technologies which use different physical principles and automatic systems to separate by size, density, type of material, colour, kind of metal, etc. As in the sorting lines, the materials are identified but using automated systems which sort and separate the waste then store and sometimes conditioning to recycling or valorisation.

Some of these technologies required in the recycling sector in Mexico are:

a. Optical multiplexer sorting systems

b. By density sorting systems

c. Magnetic separation systems

d. Trommels and screens

e. Conveyors

Food Waste and organics

Approximately one third of the total food produced for human consumption –equivalent to 1.3 billion tonnes– is lost or wasted annually. In Mexico, losses can be found in different links of the corresponding food value chain, for instance: 28 % occurs at production; 28 % at consumption, 22 % during handling and storage, 17 % in the market and during distribution and, finally, 6 % during processing (UN Environment, 2018). Mexico losses reach 37 % of the food produced in the country (approximately 30 thousand tonnes a day).

Composting

Cities can transform collected organic materials to drive regenerative peri-urban food production. Currently in cities, the most common management processes for organic materials are composting, anaerobic digestion, and wastewater treatment. The organic fertilisers resulting from these processes include compost and biodigestate, which – when compliant with regulations – can be returned to peri-urban farms to re-nurish soils and potentially increase yields without putting crop quality or safety at risk. Compost and biodigestate both contain carbon and nutrients. However, their properties vary due to their respective treatment processes, and the type of organic materials from which they are made.

Innovation can make organic fertilisers easier to use and economically competitive with conventional synthetic fertilisers. A number of companies such as Lystek Inc., Soil Food, Ostara, and WISErg are demonstrating that such innovation is possible. Several interventions help enhance the quality of organic fertilisers (Ellen Macarthur Fundation, 2019). For example, the recycling and recovery company SUEZ produces compost enriched with calcium carbonate extracted from sludge produced by a paper mill plant located in the southwest of France. Product certification was achieved by local authorities. The plant produced 30,000 tonnes per year of enhanced compost, sold via two main cooperatives at twice the value of traditional compost, responding to the needs of local farmers to reduce soil acidity (Ellen Macarthur Fundation, 2019).

Digital Innovation

Digital platforms can play an important role in getting organic resources from where they are produced to where they are needed. One such example is the partnership of Rochester Institute of Technology with New York State to create an Organic Resource Locator, a web-based mapping tool that provides state-wide information on organic production and utilisation. Similarly, SUEZ has developed Organix, a digital marketplace for organic resources, that allows organic producers to find the right and proximate solutions for their waste, for example to locate AD recovery centres (Ellen Macarthur Fundation, 2019).

MATERIALS AND BIOENERGY

Biomaterial

3 examples of usage of food waste as a biomaterial is describe below:

- Ricehouse – transforming rice husks into high-performance construction materials for buildings
- Pigmento and Mancha – creating safe 'organic' dyes for textiles and other products from food by-products, such as coffee, saffron, and cabbage
- Peel Pioneers – turning chemicals from citrus peels into cosmetics and cleaning products

Further information:

https://www.ellenmacarthurfoundation.org/publications/cities-and-circular-economy-for-food

Plastic Waste

Plastic waste and pollution have captured the attention of the public, governments, and businesses around the world. The search for solutions has started, and there is growing recognition that addressing the symptoms through clean-ups is not enough. A systemic shift tackling the root causes is required: a transition towards a circular economy for plastic, in which plastic never becomes waste (Ellen Macarthur Fundation, 2018). Therefore, there is now a huge potential market for innovative technologies related to circularity of plastic.

The New Plastics Economy Global Commitment unites businesses, governments, and other organizations behind a common vision and targets to address plastic waste and pollution at its source. It is led by the Ellen MacArthur Foundation in collaboration with UN Environment. Launched in October 2018, the Global Commitment already unites more than 350 organizations on its common vision of a circular economy for plastics, keeping plastics in the economy and out of the ocean.

For plastic packaging, specifically, this vision for a circular economy is defined by six characteristics:

1. Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority
2. Reuse models are applied where relevant, reducing the need for single-use packaging
3. All plastic packaging is 100% reusable, recyclable, or compostable
4. All plastic packaging is reused, recycled, or composted in practice
5. The use of plastics is fully decoupled from the consumption of finite resources
6. All plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected

In Mexico, practically all the industry related to the production, use and handling of packaging and plastic containers represented by ANIPAC, ANIQ, CONMEXICO and ECOCE has signed the Global Pact for what investments and substantial changes are expected in the value chain, especially taking into account of the trend of bans on plastics pursued by NGOs international as GreenPeace and national.

Further information:

http://responsabilidad.anipac.com/economia-circular-2

Electrical Waste and electronic equipment

Just like in the rest of the world, the production, consumption and disposal of electronic and electrical devices have grown in the region and the country, which has led to the generation of a growing volume of waste from these products at the end of their useful life. The progressive offer of equipment and new electronic devices, as well as intensive advertising campaigns and more convenient prices, coupled with a general improvement in purchasing power, have increased consumption of these types of products, making this the fastest-growing waste stream worldwide, due to the short lifespan of some of these products that are often not designed with their potential for recycling in mind (UN Environment, 2018).

Electronic devices are made up of a series of components that contain toxic materials and substances such as lead, cadmium, mercury, polychlorinated biphenyls (PCB), among others; together with materials that once incinerated in inadequate conditions are forerunners of other toxic substances such as dioxins and furans. This waste is generated from the improper disposal of televisions, computers, media players, land line phones and mobile phones, displays, keypads, game consoles, cables and chargers, hard disks, printers, scanners and faxes (UNU-IAS, 2015) .

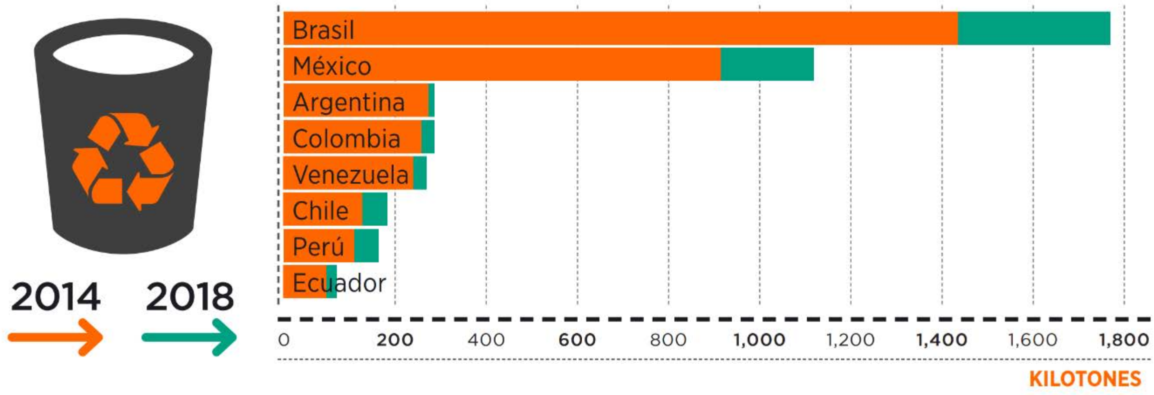

Figure 28. Main markets of eWaste in LATA

Source: (UNU-IAS, 2015)

From Figure 28. we can observe that the national average generation of e-waste in 2018 was estimated at about 1,120,000 tonnes, which represented a per capita generation of 9.4 kg/capita/year (UNU-IAS, 2015). The number of mobile devices in the Mexican market has increased from 14 million in 2000 to 107 million until the first semester of 2016. This growth has raised concerns amongst mobile phone operators, device manufacturers and consumers for the adequate disposal of devices and accessories (UN Environment, 2018). On average each Mexican produced 0.034 kg of e-waste by mobile phones but as country Mexico produced almost 4,000 tonnes of mobile phones waste in 2014 (UNU-IAS, 2015).

In October 2013, mobile operators and device manufacturers made a formal commitment to promote the development of a budding environment protection culture in Mexico, through ANATEL's recycling Program, called "Programa Verde" (Green Program).

Since the Program was launched in the fall of 2013, 2.4 million phones and 583 tonnes of accessories (batteries, chargers, SIM cards and earphones) have been recycled. In general, 80 % of materials are processed in Mexico and the rest outside of the country. The growth of the Program can promote construction of local recycling plants. Today there is about 500 collection centres of mobile phones in Mexico (ANATEL, 2019).

As established in the Waste Management Plan prepared by ANATEL, they have signed and delivered to SEMARNAT eleven prestigious companies, and the Working Group in the Association is coordinated by Nokia Mexico with the participation of the recycling company BT Recycling Solutions of the Belmont Group.

Further information:

http://e-stewards.org/recycler/bt-recycling-solutions/

Construction and demolition waste (CDW)

The CDW are leftover materials not used and generated both from the demolition activities (debris) as well as from the construction of new buildings. This waste is made up of a series of fragments of partitions, stone, concrete, mortars, wood, wires, rods and ceramics, mixed up with dirt, granular materials and other components used in construction.

There are two types of the recycling plants: stationary and mobile. Stationary plants of which capacities range from 100 to 350 ton/h usually adopt higher level technologies and are typically provided with the sorting equipment for the separation of unwanted fractions. They are suitable high areas, capable of producing a high quality of product, and efficient due to the production of different recycled products of various grading. However, the initial investment of setting such a plant can be very high. Mobile plants of which capacities can reach up to 100 ton/h treat smaller quantities of CDW in temporary demolition worksites, deploy basic technologies, and typically produce low grade recycling aggregates by in-situ recycling. They are economically feasible from an amount of 5,000 to 6,000 ton/site. However, there are limited cleaning facilities in this type of installation, and therefore, the recycled product is normally of low quality. In addition, such a plant that is usually close to residential areas can cause high levels of dust and noise which can be unacceptable. If the quantity of the area is lower than a certain amount, a transfer or collection station of which capacity changes between 1-4 ton/h should also be located from an economic point of view. Such centres do not physically recycle anything, but simply sort out or classify and compact the materials and then send this to the recycling facilities. Rejected fluxes are only hazardous and untreatable materials (e.g., tar, asbestos, resins, and adhesives) and wet sludge carrying ultra-fine mixed particles (Ulubeyli, Kazaz, & Arslan, 2017).

For instance, in Mexico, "Concretos reciclados" is one of the places for this purpose. It is located in the Iztapalapa delegation; It is a private recycling plant where only 3% of the waste generated in the city is processed, although the plant has an operating capacity of 2,000 tons per day, that is, close to 30%. It only handles concrete to produce aggregates such as gravels and sands.

The NADF-007-RNAT-2004 and the NTEA-011-SMA-RS-2008 policies establish the requirements for the management of CDW in Mexico City and in the state of Mexico. Given the low reuse and recycling percentages, technological opportunities are high for the installation of crushing plants and selection of aggregates for their future use in construction or civil works.

Further information:

http://www.concretosreciclados.com.mx/

Home appliances waste

Household appliances are universal and an integral part of our daily life. To produce and supply these products, large amounts of raw materials are used every year, and the installed products in homes represent even larger volumes of materials (CECED, 2017).

Waste from home appliances is made up, mostly, of materials that can be reused: iron, copper, aluminium, lead, tin, plastics, epoxies, ceramics, etc. It should be noted that in Mexico it is a common practice that when a device is no longer needed in a household, it is not immediately transformed into waste, but is reused by other people with fewer resources close to the family circle (INECC, 2012).

There is an opportunity to address the issues of reuse and recycling of home appliances by setting up Integrated Management Systems from the manufacturer until the end consumer that are responsible for the collection, transport, storage and recycling of a determined type of waste and to monitor all operations and disposal sites. Another opportunity calls for the introduction of liquid nitrogen installations in the treatment plants to separate the chlorofluorocarbon (CFC) from refrigerators, apart from separators for ferric and non-ferric metals, polyurethane, oils, etc. (CECED, 2017).

Further information:

https://www.applia-europe.eu/

End of life vehicles

The end of life vehicles represents a significant problem in Mexico due to the fast-paced growth in the current vehicle fleet, among which are included second hand vehicles coming from the United States, and implicitly the imminent growth of this type of waste. The lifespan of vehicles can vary from one country to the next, generally being shorter in developed countries than in developing countries. By the end of this period, automobiles are wastes comprising a wide variety of materials, such as various metals, plastics, glass, fluids, etc.

Because of their design and manufacture, they also include hazardous waste, such as lead-acid batteries, lubricant oils, filters, explosive material from airbags, coolants, electronic circuits, etc.; therefore, it is very important to have suitable management schemes for this waste stream. ELVs have a high potential for recycling, because their average composition has the following general characteristics (UN Environment, 2018):

- 68% ferrous metals
- 9% plastics (some chlorinated or with brominated flame retardants)
- 8% non-ferrous metals
- 6% glass and rubber
- 9% other materials (textiles, batteries, fluids, electric components, etc.)

In 2012 Mexico published its Plan de Manejo de Vehículos al Final de su Vida Útil (SEMARNAT, 2012), (Management plan for vehicles at the end of the useful life) which defines an ELVs as a vehicle that meets some of the following conditions: it has been destroyed in a collision; it is inoperable due to mechanical failures; its obsolescence makes it unaffordable to keep it working; or was abandoned in a public place. The Management Plan is

only applicable to light vehicles (weighing under 3.5 tonnes), and its goals are:

- Avoiding environmental pollution generated by the inadequate management of this waste

- Achieving the maximum recovery per vehicle
- Having a comprehensive management control system for ELVs, under the shared responsibility amongst stakeholders' scheme

The Plan reports the value of 837,000 vehicles for disposal for the year 2012. The ELVs generation mechanisms in Mexico involve a specific element since it is next to the US, because, aside from the new domestically produced and imported vehicles, the country also legally receives a significant number of used automobiles (more than 10 years old) from the neighbouring country, which in 2007 amounted to 1,221,144 units, and close to four million units between 2005 and 2010 (amongst the externalities inherent to this activity, it is estimated that "in the border cities of the state of Baja California, more than 85 % of CO emissions are attributable to imported used vehicles, whereas less than 15 % is attributable to national used vehicles"). In addition to this are illegally imported used vehicles, for which no data are reported in the Management Plan. There are ten companies authorized to destroy ELVs in the country, and 27 reception sites.

Further information:

http://www.semarnat.gob.mx/archivosanteriores/temas/residuos/vehiculos/Documents/plan-manejo-vehiculos.pdf

Tyres

Used tyres and their waste are a considerable environmental problem in Mexico. These tyres are disposed in house courtyards, illegal landfills, public roads and public and private collection centres, representing a "shelter" for pests, rodents and insects that are a source of diseases and add to the additional risk for the environment and human health in case of a fire in the disposal sites.

The National Association of Tyre Suppliers and Renewing Plants (ANDELLAC, in Spanish), the National Association of Tyre Importers (ANILLAC, in Spanish) and the National Chamber of the Coal Industry (CNIH) published in 2013 the Plan de manejo de neumáticos usados de desecho [Management plan for used waste tyres], in accordance with the applicable Official Mexican Standard.

According to the above Plan, 28,900 million tyres are disposed of every year in Mexico. The Mexican tyre market is very peculiar in the region because of the proximity to the US and its close connection to the used automobile market. Aside from producing and importing new tyres, Mexico imports from the US used tyres to be placed in vehicles (1,065,000 units in 2012; 3.7 % of the national market), and it also imports used tyres for rethreading (1,082,000 in 2012) (UN Environment, 2018).

This has led to the creation of joint Programs for tackling these and other types of waste on both sides of the 3,200-km border between the two countries. This two-country problem has resulted in joint workshops and seminars, as well as in the documents Scrap Tires: Handbook on Recycling Applications and Management for the U.S. and Mexico, and in the so called Propuesta de Estrategia y Política Pública para el Manejo Integral de Llantas de Desecho en la Región Fronteriza

[Strategy and Public Policy Proposal for the Comprehensive Management of Waste Tires in the Border Region]. As for the recovery and valorisation of out of border tires in Mexico, in 2011, 2.6 % of energy consumption in the cement industry came from using tires as replacement for conventional fuel, which represents close to 8,360,000 tires used every year (UN Environment, 2018).

Currently, in Mexico, 5% of tyres is recycled, 2% is used for energy generations, 2% is disposed in authorized collection centres and the remaining 91% is abandoned or used without control.

A recycling opportunity for used tyres, which is widely spread in Europe, is to use them as alternative fuel in cement plants, given their high calorific value. Another opportunity is to recycle them for asphalt pavement or for running tracks.

Further information:

http://reciclallantas.org.mx/anillac/index.html

The Enabling Environment in Solid Waste Management

6.1.2. Policy and Legislation

Legislation

The dispositions to regulation and control of the waste sector in Mexico are covered in the Constitution of Mexican United States, the General Law of Ecological Equilibrium and Environment Protection, the General Law for Prevention and Integral Management of Waste, the General Law of Health, Mexican Official Standards, Technical Standards and State Laws and its regulations, that currently constitutes the legal framework for Mexico in this field.

The Constitution of Mexican United States established an accord to article 115, fraction III, that municipalities are in charge of the function and clean up services, collection, treatment and waste final disposal, therefore municipalities are the legitimate authorities to carry out the provision of cleaning services previously commented. Generally, this attribution is ratified for the State Constitutions and supported by the State Law of Ecological Equilibrium and environmental protection. This framework serves as a reference to establish the general guidelines for local regulations and better governance and particularly of municipal sanitations regulations.

The General Law of Ecological Equilibrium and Environment Protection (LGEEPA for its acronym in Spanish) gives attributions to the Federal Government in emission field of Mexican Official Standards (NOM for its acronym in Spanish) applicable for all types of waste, plus it provides the possibilities to agreeing with states the intervention regarding the control of low hazard waste. Although the LGEEPA does not raise obligations for solid waste generators, since this is a matter of states and municipalities, it empowers to environmental federal authority to establish technical rules for storage, collections, transport, treatment and the final disposal of municipal solid waste. Also, the LGEEPA raises the technical rules to prevent and control the effects that over the environment could happen for the generation, storage, collection, transport, treatment and final disposal of solid waste and no dangerous industrial waste.

The States, across its legislatures, has commissioned legislation in this field and have administrative authorities, dependent on state civil service, to intervene the support of competent municipal authorities, especially in matters relating to urban development. The municipalities, through the council, issued regulations in the matter, in so far as the councillors acts like activities supervisors; also having administrative institutions that attend directly to the public service consisting of: street sweeping, collection, transport, treatment and final disposal of solid waste.

Technical Policies

- NOM-083-SEMARNAT-2003, It establishes the requirements for final disposal of municipal and industrial solid waste while they are not considered as hazardous.

It's important to note that currently in Mexico, it is not obligatory to exploit the biogas produced in landfills, even in this Official Regulation it is not specified technical security aspects or operating parameters. SEMARNAT and PROFEPA are the institutions responsible for monitoring compliance with this regulation.

- NOM-052-SEMARNAT-2005, It establishes the characteristics, procedures of identifying and classification of dangerous wastes.

Especially for energy recovery systems it is required to revise that there are some considered hazardous waste with high calorific value as some of the classified in the "Listado 4", and there is only one treatment approved for this material: incineration. It is important to check in NOM-054-SEMARNAT-1993, the incompatibility between two or more hazardous waste.

- NOM-098-SEMARNAT-2002, establishes the operation specs and the maximum bounds of related pollutants.

In Mexico it is considered as “incineration” the gasification technology, pyrolysis and plasma, when fuel products are subjected to combustion in an oxygen-rich environment. Fortunately, in the recently publishes law (2014) “Ley de la Industria Eléctrica”, these technologies are classified as Clean Energy, as long as they accomplish the requirements in toxic gas emissions.

- NOM-161-SEMARNAT-2011, It establishes the criteria to classify Special Management Waste and determines which are obligated to have a Management Plan.

This regulation is so far the most powerful tool to encourage the use of industrial and commercial waste because it states the obligation to have a record of the quantity and characteristics of waste generated; also begins to recognize that within the waste can be a great economic value which needs appropriate processes to generate profitability in the management and not just costs.

This regulation is complemented by:

NOM-004-SEMARNAT-2002 which refers to sludge from water treatment plant and biosolids.

NOM-087-SEMARNAT-SAA1-2002, marking procedures for handling biological-infectious hazardous waste.

- NOM-157-SEMARNAT-2009, It establishes the elements and procedures to implement management plans for mining waste.

Like the previous, NOM-161 this regulation is a milestone and is an important tool for low carbon technologies in this industry that for every ton of product produced generate up to 10 times more waste.

It is recommended that related to waste management permits consult the Ministry of Environment: SEMARNAT.

Review the NOMs issued by the Ministry because in them the lists of municipal solid waste and require special handling management plan, criteria, type of plan and the elements and procedures to be taken into consideration to be placed.

If applying as a major and small generator of hazardous waste will need to obtain a registration with SEMARNAT as a generator.

The largest generators of municipal solid waste and special management are required to register with municipal authorities, establish management plans for the waste they generate large volumes and subject to registration of competent authorities, if required to be changed or updated.

Should be subject or liable to generate a plan for hazardous waste management, this should be recorded before the SEMARNAT.

In both NOMs governing technologies or processes of recycling, treatment, incineration, gasification, plasma, or other thermolysis is not issued, SEMARNAT may request the executive service provider and develop a testing protocol project, provided that the technology or process is innovative and there is no experience with it.

In case of an emergency related to the comprehensive management of waste should resort to civil protection.

In the case of the generation of hazardous waste considered as infectious, SEMARNAT, together with the Ministry of Health will issue official Mexican standards by which their management and disposal is regulated.

Governance

In Mexico, the waste management sector is organised according to three types of waste: (i) municipal solid waste (MSW); (ii) special handling waste; and (iii) hazardous waste. Each type accounts for a different value chain given the fact that the Public Administration is involved at different levels in the management process. Firstly, municipalities are responsible for the management of municipal solid waste, secondly, states are responsible special handling waste and lastly federal authorities oversee hazardous waste. A telling feature of the Mexican system is that the municipalities do not charge fees for the collection, treatment and disposal of waste, which impairs a correct waste management. In addition, the only regulated phase in the whole process is the final disposal.

Recently, the new vision for waste management in the country has been published and, in this declaration, the following 6 Guiding Principles of the waste management policy are established:

- Sustainable development. Consider the integrity of the development of the country, with economic, social and environmental aspects.
- Circular economy. Establish the bases and develop the mechanisms and instruments to implement a circular economy approach that strengthens the sustainable management of materials, with a zero-waste vision.
- Fight against corruption and transparency in public management. Prevent and avoid discretion in the provision and collection of services.
- Attention to vulnerable populations and social justice. Provide training and service to isolated populations with few inhabitants. Training of cooperatives and work groups to collaborate in the collection, collection and management of waste.
- Reduce the risk and impacts on health and the environment. Avoid the proliferation of diseases and harmful effects on health due to the inadequate management of waste, as well as the risk and impacts on the environment.
- Social welfare and reduction of inequality. Expand service coverage and serve communities under 10 thousand inhabitants. Establish coordination and follow-up

mechanisms to achieve harmonization and articulation with programs and policies related to gender equality.

6.1.3. Cultural and Social aspects to consider

In practically every municipality in the region, segregation is carried out in all stages of waste management: at the source, sweeping, collection, transfer and of course at final disposal sites, mainly by waste pickers (WP). Determining the size of the population of waste pickers has always been a complex task due to the informal nature of the activity, amongst other factors. Some reports cite a number of 3.8 million people in the upper limit in Latin America and the Caribbean.

The Regional Initiative for Inclusive Recycling (IRR) reported in 2013 that "The population of waste pickers in LAC aggregates around four million people" (Accenture, 2013). The Red Latinoamericana de Recicladores (Latin American Recyclers Network) is also a source of information about inclusive recycling in the region. When properly supported and organized, informal recycling can create employment, improve local industrial competitiveness, reduce poverty, and reduce municipal spending on solid waste management and social services.

In 2006, the World Bank Group's International Finance Corporation (IFC) partnered with a Mexican company, PetStar, to finance a recycling plant that processes polyethylene terephthalate (PET), a common material in plastic bottles and food packaging. Because of low recycling rates in Mexico, sourcing a steady supply of raw PET from municipal recycling programs was not feasible.

As a result, the project identified waste pickers as natural partners in collecting used PET products across the country. PetStar and the IFC worked together to generate socially responsible partnerships with waste picking communities that not only provided employment, but addressed issues with working conditions, organization and advocacy, and child labor. By partnering with the major beverage manufacturer Coca-Cola, PetStar found a guaranteed buyer for recycled plastic. This consistent revenue stream enabled PetStar to contract with informal workers at a fair, consistent wage. PetStar and the IFC's unique, vertically integrated approach to recycling is not only profitable but socially responsible for waste pickers and the environment (World Bank Group, 2018). Table 24 gives an overview of the programs and relevant projects in Waste Management.

Table 24: Programs and relevant projects in Waste Management

PROGRAMME NAME	SCOPE	GENERAL	SPECIFIC CONTEXT
Several waste			
Clean up Mexico	National	The program has collected tons of garbage	Spreading this kind of event raises awareness among citizens, best practices inducing them apart, for a more efficient and effective recycling.
Barter of waste			

Barter Market	Mexico City	Still remaining one third of the food converted to waste	By promoting the exchange of food waste, improve separate collection process, saving costs and causing a more efficient system.
Battery recycle			
Grupo Mex Ambiental	Mexico City	In Mexico are still small efforts to give proper management of this waste	His specialty is treating batteries, both alkaline and cell. It is a program separate from the trash thousands of alkaline, rechargeable batteries for reuse as raw material in industry. Shopping malls can approach them to ask for a container facility at no cost for used batteries and cell phones. It is also the first self-funded plan nationwide in Mexico.
TES-AMM Latin America	Mexico City		This company specializes in processing electronic waste, seeking to maximize recovery and minimize environmental damage. Among its services, the recycling of batteries, metal recovery, collection and safe destruction of the elements is, among others. Recommends together several teams before taking them to its centre.
Manejo Responsable de Pilas	Mexico City		The program of responsible management of batteries and cell phones in the DF emphasizes the responsibility that people should have to replace your mobile phone or batteries usually contain toxic substances such as mercury, cadmium, nickel and manganese.
Recycling of electronic cards			
Kega	Mexico City		They offer recycling of electronic cards. It is a chemical company which is also given the task of reducing the optimized cost management and disposal of waste environmental impact.
Recycling electronic			

Proambi	National	Despite the existence of these programs, yet the rate of recovery of electronics is very low, which would have a very important impact to avoid dumping their waste in the open, so it becomes an excellent window of opportunity to do business.	Mexican company dedicated to the end position and recycling of electronic equipment. Processes all components under international standards, 100 % neutralizing the toxic content in this waste and following a completely mechanical and ecological process. Meet all the standards for certification ISO9001 and ISO14001. Nowadays, together with “Comercial Mexicana” has 70 permanent collection centers across the Republic to waste equipment considered obsolete electronic waste.
Ret Foundation	Mexico City		This organization is an alternative to properly channel the waste. Its main function is the collection, reuse and recycling of technological devices. The re-use of resources to maximize the benefit that can be obtained from various technical and material elements, transforming those who are no longer useful for some people, valuable tools for further development and reduce emissions.
Eco Azteca	Mexico City		Managers in collection and destruction with or without cost of cell phones, CPUs, monitors, fax, terminals, televisions, printers, electronics, measurement equipment, interconnect cables, no breaks, switches, landlines and routers. Aimed at SMBs, large enterprises, government entities and individuals constantly renewing, and store equipment obsolete by not having a waste destination or failing that for administrative reasons are forced to retain, until the necessary cycles are met.
REMSA	Mexico City		Mexican company receiving televisions, DVD, CD, MP3, CPUs, telecommunication equipment, video game consoles, e-cards, cell phones, palmtops, iPods, decoders, network equipment, fax machines and laptops. It has patented processes and infrastructure to capture, collect, separate and recycle all materials generated specific products such as

			monitor glass, plastics, electronic cards and metals (ferrous and nonferrous).
Recall International	National		International company dedicated to buy cell phones for recycling. Those interested can take it to its offices or communicate through their website. Offer cost effective solutions for the collection, collection and recycling of used cell phones to social organizations, governments, businesses and users. They have alliances with the Intercontinental Association of Electronics Recyclers, which aims to promote cleaner and less use of toxic production.
Reciclatrón	Mexico City		Collect and recycle electronic

SWOT Analysis

- **Size and diversity of market**
  - MSW
  - Special Handling
  - Hazardous
- **Presence of international companies**
  - Global vision
  - Global goals
  - Global practices
- **Maturity of recycling industry**
  - Plastics (PET)
- **Free trade agreement between Mexico and the European Union (TLCUEM)**
  - Machinery and equipment

- **Lack of compliance with environmental legislation**
  - Low number of federal inspectors
  - Not all of Federal States have Environmental Ministry
- **Responsibility of municipalities to manage waste**
  - Lack of technical capabilities
  - Lack of budget
- **No clear federal guidelines on treatment and recycling**
- **Shortage of funding**
  - No more grants from CONACYT to build prototypes or pilot projects

- **Public Budget deficit in the following years**
- **Government priority to meet other agendas**
  - Security, education, etc.
- **Impossibility of some subnational governments to charge for waste management**
- **Informality in the recycling industry**
  - Metals

- **New Zero Waste National Vision**
  - Including Circular Economy
  - Closing open dumpsites
- **Political unification of the powers**
  - Financial resources to municipalities
  - Political stability
- **Government decentralization**
  - SEMARNAT in Yucatan
- **Global Commitments**
  - Paris Agreement

6.1.4. Key events/fairs/conferences

- http://www.residuosexpo.com/RE2018/es/
- https://www.thegreenexpo.com.mx/2018/es/
- https://expoenverdeser.com/
- https://www.earthxmexico.org/

6.1.5. Existing reports/information for further reading

It is highly recommended to review the results and publications of the recently completed ENRES Program (Energy from waste) promoted by GIZ, SEMARNAT and SENER.

ENRES Program

1. Analysis of public policy instruments to stimulate the energy recovery of urban waste in Mexico and proposals to improve and expand them

Download

2. Technical guide for the management and use of biogas in wastewater treatment plants

Download

3. Sources of financial resources available for energy use projects of urban solid waste and special management in Mexico

Download

4. Potential for the energy recovery of urban waste in Mexico, through co-processing in cement kilns

Download

5. Waste-to-Energy Options in Municipal Solid Waste Management

Download

Table 25:List of companies, potential clients or partners, as well as clusters or sector associations

Stage	Company	Brief
Integrated Management	Grupo PASA https://www.pasa.mx/NOSOTROS	It is the leading brand in total waste management with more than 40,000 customers nationwide. 21 Municipal Contracts 22 Landfills 45 Private Collectors 18 Collections of Hazardous Waste 5 Transfer Stations
	Veolia Mexico https://www.veolia.com.mx/ A couple of years ago it promoted one the biggest projects of waste to energy in Mexico https://www.veolia.com.mx/comunicados-de-prensa/veolia-convertira-en-energia-los-residuos-de-la-ciudad-de-mexico	In Mexico, Veolia has 25 years of operation, is a reference in water and waste services for municipalities and industries, through the annual management of 2.3 million tons of solid waste in treatment and 800 thousand in collection; approximate potabilization of 500,000 million cubic meters of water reaching more than 20 served cities and 13 million users in its two activities. A couple of years ago it promoted one the biggest projects of waste to energy in Mexico https://www.veolia.com.mx/comunicados-de-prensa/veolia-

	convertira-en-energia-los-residuos-de-la-ciudad-de-mexico
TECMED https://www.tecmedmx.com/	TECMED is a Mexican company of Spanish capital with presence in several states of the Mexican Republic, which specializes in processes that are related to the integral management of solid waste, from its collection, transfer, valuation, transfer and final disposal. Tecmed also deals with environmental engineering projects, closure, sealing and final closure of garbage dumps and landfills, control and reduction of environmental liabilities and projects for the use of biogas in sanitary landfills, with alternative generation of renewable electric energy.
RED Ambiental http://www.redambiental.com/	It is a company that offers domiciliary and industrial collection services in addition to operating several landfills, transfer stations and treatment plants nationwide.
RESA Rellenos Sanitarios http://www.resamx.com/somos.html	Operates municipal management systems mainly in Puebla
AMEXA	Association of environmental companies that encompasses several of the leading operators and developers of integrated

	http://www.amexa.org.mx/medioambiente/index.php	waste management projects in Mexico
Management	Innovative Group https://www.icg-la.com/	Transnational company specialized in creating comprehensive programs for waste management. Management, Zero Waste Certification, Software and Hardware for measurement, control and recovery of waste.
	VALMET https://www.valmet.com/es/contactenos/mexico/	Company specialized in automation, control and operation of recycling industries
Collection	PRO AMBIENTE https://www.wazte.mx/	Waste collection company with digital programming platform
	AMBIENTUM https://www.ambientum.com.mx/	Company that offers urban solid waste collection and special non-hazardous handling services
	ASECA https://www.aseca.com/	It offers services of: Collection of Non-Hazardous Waste 20 years of experience in the integral management of

		Infectious Biological Hazardous Wastes Collection of Industrial Waste with key CRETI Waste Collection through Wastebaskets We have programs for the management and control of industrial waste with CRETI key generated by the activities of various companies, industries and institutions.
Handling	CIASA Commercial http://ciasa.prensas.bramidan.mx/	Waste compaction: paper, cardboard, PET, etc.
	GRUAS ARTICULADAS CHATARRERAS http://gruas-chatarreras.com.mx/	Company dedicated to the sale, installation and repair of articulated cranes for the scrap and forestry industry.
Transport	Keith Walking Floor http://www.keithwalkingfloor.com/	Mobile floor system keith® walking floor® for auto download of solid municipal waste in semi-trailers, trucks, containers and seasonal applications
Recycling	GTA Ambiental	Integrating company of projects of Solid, Urban, Commercial and Industrial Waste Management from the production of transfer

	http://gtaambiental.com/	plants to optimize their logistics, until the obtaining of recyclable and separated organic materials for their later use as materials or sources of clean energies and the rejection management as alternative fuel or biomass derived from waste (Green CDR).
	BIOPAPEL https://www.biopappel.com/	The largest paper and paper products manufacturer in Mexico and Latin America. Annually produce more than 1.5 million tons of paper, double the second paper manufacturer in Mexico. Additionally, they manufacture 1.2 million tons per year of corrugated paper and packaging products.
	MARRSA http://www.marssa.com.mx/	Turnkey projects; from the design, installation, training and maintenance of Municipal Recovery Facilities
FOOD WASTE AND ORGANIC FRACTION	BAMX https://bamx.org.mx/bamx/?v=1fda4fa5605d	Made up of a network of more than 50 food banks distributed throughout the national territory, BAMX is one of the most important civil organizations in the country, as it is the only network of food banks in Mexico and is the second largest in the world.
	APT	It is the largest independent food bank in the country. It recovers food and basic goods in disuse that are still suitable for human

	https://www.apt.org.mx/	consumption and use, to deliver them to people living in poverty.
	ALDEA VERDE https://www.aldeaverde.mx/	Leaders and national references in the sector, with more than 70 compost and vermicomposting plants assembled to date.
	IBTECH http://ibtech.com.mx/	IBTech® is a Mexican company dedicated to the diagnosis, design, construction, start-up and operation of water conditioning plants and wastewater treatment, as well as biogas generation plants and energy from biomass.
	SUEMA www.suema.com.mx	It is an innovation agency focused on the development of circular economy projects in the organic cycle and plastic cycle. They have built the first urban biogas system to treat organic waste produce in public markets in Mexico City.
Plastic Waste	PETSTAR http://www.petstar.mx/	The PET recycling plant largest food grade in the world
	CPR http://www.cprmex.net/	Founded in 2009, CPR MEX is associated with VALGROUP, which has been active in several countries for more than 30 years in the plastic products transformation and marketing market. The company specializes

	in the manufacture of recycled resins.
ECOCE http://www.ecoce.org.mx/	It is an environmental civil association created and sponsored by the consumer products industry. Leader in environmental sustainability and tool of Corporate Social Responsibility (CSR) of our associates, through the recovery of packaging waste and packaging of its products, for recycling in Mexico. We are the first organization in Mexico to propose concrete actions on the proper handling of packaging and packaging waste.
ANIPAC https://anipac.com/	It is an organization with greater representation of the sector, since it is present throughout the supply chain: from producers and distributors of raw materials, recyclers, producers and distributors of machinery and equipment, and plastic transformers in all its forms.
ANIQ http://www.aniq.org.mx/webpublico/	It currently represents more than 95% of the private production of chemicals in our country through around 258 companies of different sizes and activities within the sector that are voluntarily affiliated.
INBOPLAST https://www.inboplast.com.mx/	Inboplast is an association of industrial companies, manufacturers of plastic bags and plastic packaging, concerned and occupied by the future of the planet, which through the

		continuous innovation of its products, as well as the efficient management of the natural resources it employs, allows the protection and maintenance of the environment.
	INDUPLASTIC https://induplastic.com/	Company dedicated to the recycling of all types of plastics and the maquila
CONSTRUCTION & DEMOLITION WASTE	CONCRETOS RECICLADOS http://www.concretosreciclados.com.mx/es/index.php	Concretos Reciclados is a Mexican company dedicated to the recycling of construction waste, founded in 2004.
	CMIC http://www.cmic.org/	The CMIC is a public, autonomous institution with its own legal personality and jurisdiction throughout the territory of the Mexican Republic that was established on March 23, 1953 and currently has about 12 thousand members.
	SUMe http://sume.org.mx/	SUMe Sustainability for Mexico A.C. is a nonprofit association whose vision is to join efforts towards a sustainable Mexico in order to improve the quality of life of all through joint actions and wills. SUMe is officially the Established Council for Mexico of the World Green Building Council (WGBC) and is recognized by the US Green Building Council (USGBC) as an Education Partner.

e-WASTE	ANATEL http://www.anatel.org.mx/	Currently ANATEL has 52 Associate members that represent 90% of the added value that the telecommunications industry brings to the Mexican economy.
	CANIETI http://www.canieti.org/	The National Chamber of the Electronics Industry of Telecommunications and Information Technology has more than 80 years of life in our country, the Chamber is integrated by more than 1000 affiliated companies throughout Mexico
HOME APPLIANCE	ANFAD http://anfad.org.mx/	The ANFAD has 28 associated companies, which are divided into 7 representative sectors nationwide. It is an organization whose objective is to guarantee the development of the industry of domestic appliances integrated by a General Assembly of Associates and a Board of Directors, constituted by the most important representatives of the various companies belonging to the category.
Hazardous waste	CIMARI http://www.cimari.com.mx/	Company dedicated to the handling, treatment and disposal of hazardous waste

Annex II: Wastewater Management Sector Trends, Legislation, Policy and the Enabling Environment.

— Key Stakeholders in the Mexican Wastewater Treatment Sector

Within the wastewater treatment sector in Mexico, the key stakeholders are divided into the public sector, the private sector (associations and companies), the research and academic institutions, NGOs and funding institutions. Figure 29.0 shows a general view of the structure of the wastewater sector in Mexico, showing the main entities involved in each step of water management process: from knowledge generation, technology development and application, support and intermediation to public policy.

1. Knowledge generation	• **Universities** • Universidad Autónoma de México (UNAM) • Universidad Autónoma de Chapingo • Universidad autónoma Metropolitana (UAM) • Universidad de las Américas in Puebla • TEC de Monterrey
2. Technology development	• **Research & Technology Centers** • Mario Molina Centre • Centre for Environmental Quality • Centro del Agua para América Latina y el Caribe • National Institute of Ecology and Climate Change • National Institute for Water Technology
3. Technology application	• **Companies** • Acciona Group • Atlatec S.A. • Grupo CARSO S.A. • OHL, Medio Ambiente • VEOLIA Mexico
4. Support and intermediation	• **Clusters & Associations** • AMEHIDRO • ANEAS • ANNCA: National Association for a new culture of water • CCMEX: Cleantech Cluster Mexico • CESPEDES
5. Public policy	• **Public entities** • CONAGUA • SEMARNAT • Watershed councils • SEDUVI • CESPEDES: World Business Council for Sustainable Development

Figure 29. Structure and entities involved in Mexican water sector

Next, the public and private parts of the water sector in Mexico are discussed, showing the main entities involved.

— The Public sector

Concerning the public part of the sector the following institutions are the key players involved in the water public sector:

- Banks and funding institutions

BANOBRAS: National Bank for Public Works

FIRA: Trust funds related to Agriculture

- Public authorities

CONAGUA: National Commission for Water

SAGARPA: Ministry of Economy and Production, through the Secretaries of Agriculture, Livestock, Fisheries and Food

SEDATU: Ministry for Land Planning and Development

SEMARNAT: Ministry of Environment and Natural Resources

SFNA: Undersecretary for Environmental Support and Regulations

SGPA: Undersecretary for Management of Environmental Conservation

SHCP: Ministry of Finance

SPPA: Undersecretary for Planning and Environmental Policy in SEMARNAT

- National institutions

CENAPRED: National Disaster Prevention Centre

CONACYT: National Council for Science and Technology

CONANP: National Commission for Protected Areas

INE: National Ecology Institute

PROFEPA: State Attorney for the Protection of the Environment

For European entities looking to work in Mexico, CONAGUA would be the main institution to liaise with, as it is the entity in charge of launching tenders and adjudicating winning proposals and funding wastewater projects in Mexico. CONAGUA is subordinated to SEMARNAT, which is the Secretary of Environment and Natural Resources. Its main functions include the development of the national water policy; administering the rights for water use and wastewater discharge; planning, irrigation and developing drainage systems; managing emergency and natural disasters and managing investment in the water sector in Mexico. Also, there are international funding agencies that fund water projects in Mexico (GIZ, World Bank, IDB, etc.)

Other public entities involved in water management in Mexico are the State Government and Municipal Governments. State governments have responsibilities for planning, regulating, developing infrastructure for water resources and, in some cases, directly providing water and sanitation. Municipalities are responsible for providing water and, generally, sanitation services.

— Private sector

The water sector has several private institutions that play an important role in national water management. They can be divided between individual companies and clusters or associations. They are listed in Annex 2A. Many of these companies are Mexican (e.g. Atlatec, Controladora de Operaciones e Infraestructura S.A.) but there is also a strong link with Spanish (e.g. Acciona, Sacyr) and other European entities (Alfa Laval).

Companies are often associated in clusters or associations that operate jointly in the Mexican water sector. Amongst them, AMEXA (Mexican Association for Environmental Companies) links companies that provide services in different sectors to fight against environmental deterioration, including projects related to the improvement of water management. CESPEDES is another relevant companies' cluster that develop public policies in terms of sustainability with a business point of view. This association represents Mexican environmental sector in national and international forums.

— Research sector

There is a series of academic institutions that focus, to some extent, in the water sector in Mexico. The most important are listed in Annex 2B.

An example of world leading research is found in the work done by experts of UNAM (Universidad Autónoma Metropolitana) in the Instituto de Ingeniería (Engineering Institute) related to water reuse research some of it focused on increasing soil productivity (B. Jiménez Cisneros). Also, Tec de Monterrey is known for its research concerning industrial wastewater treatment with specific specialisation on membrane bioreactors. Moreover, this institution has developed several systems for rainfall water gathering and reuse. Tec de Monterrey are also one of the founding members of the "Centro de Agua para America Latina y el Caribe" (The Water Centre for Latin America and the Caribbean) which is a centre known across Latin America for its training and research on water resources research management and for specifically running the water network in Latin America and the Caribbean.

— Non-governmental organizations:

The most important NGO working on water issues in Mexico is "Agua para Todos" (Water for Everyone, http://aguaparatodos.org.mx/). This organization is focused on the protection of water resources for Mexican citizens. It is formed by local associations, social organizations, trade unions, farmers, human rights associations, local community systems, church communities, students and researchers.

The following are other NGOs that operate, to some extent, in Mexican water sector. They are presented subdivided by their associated main roles:

Sustainability and environment:

Mario Molina Center for Strategic Studies on Energy and the Environment

CTS EMBARQ Mexico: global initiative of the WRI Ross Centre for Sustainable Cities

AIDA: Interamerican Association for Environmental Defense

GREENPEACE: international NGO in Environment

I.A.P.: Environmental Groups' Union

Environmental Studies Group

Foundation for Sustainable Development

Research

Fundar Analysis and Research Centre

CIDAC: centre for development research

IMCO: Mexican Institute for Competitiveness

Climate

LARCI: Latin America Regional Climate Initiative

Poverty and human rights

OXFAM: international NGO supporting climate change measures to reduce poverty

— Funding institutions

With regards to funding mechanisms, Table 26 gives a list of the main entities involved in financial resources related to water management, operations and infrastructures in Mexico:

Table 26: Main financial sources related to water management in Mexico

Entity	Description	Finance type	Funding applications
BANOBRAS	The national development bank which helps states and municipalities finance infrastructure projects. It is the trustee of the National Infrastructure Fund (FONADIN).	Loans and Grants	Water resource development Water networks Wastewater networks Water treatment Wastewater treatment Desalination Water reuse Sludge management
Conagua	Conagua charges duties to utilities for water withdrawals and wastewater discharges. This money is collected at the national level and redistributed to states and municipalities for investments.	Grants only	
Ministry of Finance and Public Credit (Secretaria de Hacienda y Credito Publico)	Defines the funds allocated to the water sector from the federal budget, as well as approving multi-year investment programmes.	Grants only	
National Infrastructure *Fund (Fondo Nacional de* *Infraestructura, FONADIN)*	A national fund which lends and grants money to states, municipalities and private companies to develop infrastructure projects deemed socially profitable, financially secure (i.e. will generate their own revenue), and that involve the private sector. The fund is administered by BANOBRAS.	Loans and grants	

6.1.6. Sector technologies and trends

The analysis of the wastewater market in Mexico firstly it is important to identify the existing technologies and their current degree of implementation. This allows us to know the trends for improvement and the market gaps that exist, and which represent opportunities for potential collaboration between European and Mexican companies in this sector.

Sector trends

Wastewater reuse is being increasingly considered by municipal water organisations and the industrial sector to combat water scarcity. This will be an important market in the northern states, because they have a higher population, they are hubs of manufacturing and industrial activity, and have less water availability than in the south.

Being the largest wastewater treatment plant in the world, the recently built Atotonilco plant represents a crucial element in the increase in the volume of wastewater reused in Mexico. The plant provides service to 10.5 million of inhabitants and supply an irrigation area of 800.000 has. The investment was 560 million euros.

Apart from this project, the state of San Luis Potosí recently announced plans to treat wastewater to a level that can be reused in industrial and potable water supply. The El Morro plant is meant to provide treatment for 90% of San Luís Potosí wastewater. Recent initiatives such as these indicate a demand for reuse with advanced technology will be increasingly considered in the future, therefore constituting an important market opportunity.

According to data from 2014, 106 of Mexico's 653 national aquifers were in a state of over-exploitation and 31 of the country's coastal aquifers were under threat of saltwater intrusion. In recent years, Conagua has carried out large-scale studies to assess the current state of the aquifers. One of the main investments in groundwater protection in the coming years will be the creation of a national aquifer database that will provide real-time data on withdrawal and recharge rates, as well as the water quality of groundwater in different regions. The initiative is called the Information System of Aquifer Extraction Volumes (SIEVA) and is designed to provide a basis for relevant policies related to water rights, withdrawals and aquifer management. Moreover, 2012 Mexican standard NMX-AA-159-SCFI-2012 was developed with the objective of restoring the hydrologic balance and to determine ecological flows in watersheds. These aspects represent a market opportunity for companies involved in the field of water monitoring.

6.1.7. The enabling environment

Policy and legislation

Table 27 summarizes the main regulations applicable to the water sector in Mexico

Table 27: Regulation framework applicable to the water sector in Mexico

Document	Description	Policy areas	Industries targeted
Mexican Law of Public-Private Partnerships (2012)	Establishes the legal framework for developing, procuring,	-	-

	and financing PPP infrastructure projects in all sectors.		
NOM-004-ECOL-2002 (2002)	Establishes maximum allowed values for pollutants in sludge, according to different uses.	Sludge management	Utilities, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, textiles & tanneries, pharmaceutical, microelectronics, other industries
NOM-003-ECOL-1997 (1997)	Defines the maximum level of pollutants allowed in treated wastewater (both municipal and industrial) to be reused in public services such as green park and golf course irrigation, artificial recreational lakes, and car wash services.	Water reuse	Utilities
NOM-001-ECOL-1996 (1996)	Defines the maximum level of pollutants in wastewater that can be discharged into national waters.	Wastewater discharge	Utilities, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, textiles & tanneries, pharmaceutical, microelectronics, other industries
NOM-002-ECOL-1996 (1996)	Defines the types of wastewater that can be discharged into urban drainage systems.	Wastewater discharge	Utilities
NOM-127-SSA1-1994 (1994)	Regulates the quality of drinking water for human consumption	Drinking water quality	Utilities

National Water Law of 1992 (1992 (revised 2004))	The main law governing the management and distribution of water in the country, dictating everything from quality standards to private sector participation.	Drinking water quality, wastewater discharge, water reuse, environmental water quality	Utilities, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, textiles & tanneries, pharmaceutical, microelectronics, other industries
Federal Duties Law (1981)	Federal law that determines the amounts of water abstraction fees based on the availability of water in designated regions, and which government institution receives the money.	-	Utilities, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, textiles & tanneries, pharmaceutical, microelectronics, other industries

Together with this general framework, the following points reflect the current trends concerning water regulations in Mexico:

Enforcement of existing water regulations in industry: in terms of biological oxygen demand the wastewater discharge of self-supplied industries is equivalent to the municipal wastewater discharge of 300 million people. Industrial water treatment demand is higher in the north part of the country and along the US border than in other parts of the country. The government has taken a harder line with enforcement of existing environmental regulations, mainly as a means of generating revenue. Therefore, companies are now being pressured to meet prevailing discharge standards. This will enhance the adoption of more advanced water treatment technology and water solutions that more adequately address the unique scenario of a given feedwater stream. Increasingly the demand for advanced treatment will call for better design and operational support.

2012 Public-Private Partnership Law: this law sets the stakes for a larger percentage of private financing in public works projects. As such, this law will be the national level law that governs public-private partnerships (PPPs) in the coming years, not only in the water sector but in all infrastructure arenas.

New general water law: this law addresses the poor financial and technical capacities of state and municipal organisations responsible for provision as the primary challenge of the sector. The application of this law has been controversial and has gone through difficulties for its implementation. It is designed to hold municipalities more accountable and will punish bad practices and non-compliance. It is designed to depoliticise local water organisations. Conagua hopes the law will indirectly lead to more concessions and more private sector contracts as the municipal water organisations will turn to private sector expertise to become fully compliant, as well as to resolve their outstanding debt.

The private sector is typically required to finance 30-50% of infrastructure costs, usually through a combination of risk capital and finance. The most common public private partnerships model used is Design-Build-Operate-Transfer (DBOOT). All or part of a project may be offered for tender.

Once an acquisition project has been identified, the public sector must choose between three main tender models:

Direct acquisition: public body purchases directly from a supplier, showing examples of rival companies' offers to prove competitiveness. Usually used for small acquisitions of goods and services

Invitation to tender: Public body invites a small number of companies (usually less than 6) to tender offers for goods and services. Usually used for mid-level acquisitions or situations where specific skills and experience is required and restricted to national companies.

Open tender: Public body invites tenders from all interested parties, sometimes restricted to national companies but often including international enterprises. Usually used for the most expensive infrastructure projects.

— Water Agenda 2030 (Agenda del Agua 2030)

Within the official documents that frame water management policies, the Agenda del Agua 2030, establishes a series of lines of strategy for the following years. These strategies are key for market evolution and opportunities for international collaboration and can be grouped in two areas:

i. To ensure that the different catchments of the country have a solid governance structure, with enough capacity to manage water resources in a sustainable way
    - Consolidated catchment organisms in each of the big watersheds of the country
    - Operative catchment councils with capacity to concretize and carry out agreements and strategies
    - Groundwater technical committees operating in overexploited aquifers, focused on their rehabilitation
    - Associations of irrigation users in all districts with reinforced capacities to improve and modernize their units of production
    - Organisms and water companies operating at high physical and commercial efficiency levels

ii. To ensure a better and more equilibrated distribution of competences in regulation and supply of water and wastewater treatment services with responsibilities at the national, regional and municipal level to achieve a more equilibrated National System of Water Management

- Reinforce the competences and capacities of national commissions of water and wastewater and of municipal companies and organisms to provide efficient services
- Create regulatory frameworks suitable for each of the organisms dealing with their corresponding missions
- Developing joint programs and projects to deal with strategic issues for fluvial sustainability, like definition of flood zones and land use distribution
- Guarantee the availability of funding resources for the construction, improvement and rehabilitation of water and wastewater services, through the definition of tariffs, subsidies and guarantees
- Create strong financial water systems at the local, regional and national level that satisfy the sector requirements
- Establishing incentives for water users adopting sustainable behaviour
- Carry out control and vigilance tasks within the competence of each entity
- Enhance the development of technical and management capacities of each of the key actors
- Temporal substitution of the actors that are not able to achieve their objectives with a minimum efficiency

Governance

Different governmental institutions are involved in the development of the Mexican water legislation. These entities act at different regional scales and are focused on different aspects of water management. Table 28 summarizes the different entities involved in water management in Mexico:

Table 28: Main entities involved in water management in Mexico

Entity	Level	Description	Roles
Federal Attorney's Office for Environmental Protection (Procuradoría Federal de Protección al Ambiente, PROFEPA)	Federal/National	Federal organisation responsible for monitoring the quality of rivers, lakes and groundwater. PROFEPA applies sanctions for environmental violations (i.e. untreated wastewater discharge into national water bodies), and along with enforcement, it acts as an advisory body which supports companies and utilities in meeting regulations.	Environmental regulation
Federal Congress	Federal/National	Defines policies and allocates money to the water sector, and approves any new laws or	Policy and planning Finance

		regulations related to the water sector	
Mexican Institute of Water Technology (IMTA)	Federal/National	A research-oriented institution also under the auspices of SEMARNAT, which conducts studies on the development of water resources and use of technology to solve water challenges in the country.	Research and information
Ministry of Health	Federal/National	Government body responsible for setting the Mexican Official Standards for drinking water quality, which Conagua enforces.	Drinking water quality
Ministry of the Environment and National Resources (SEMARNAT)	Federal/National	Responsible for the management of the environment and the sustainable exploitation of natural resources, SEMARNAT manages the country's water and exercises this authority through Conagua.	Policy and planning Drinking water quality
The National Water Commission (Conagua)	Federal/National	Under the aegis of the Ministry of Environment and Natural Resources (SEMARNAT), Conagua acts as the autonomous authority for the management of water resources, and the developer and promoter of major water infrastructure works at the national level. It executes its work through its 13 river basin organisations, as well as local and state Conagua branches.	Policy and planning Drinking water quality Finance Water basin management Bulk water services
State Governments	Regional	32 independent states that make up the Republic of Mexico. State-level ministries regulate the water sector through tariff setting, defining standards for the design	Drinking water quality Environmental regulation

		and construction of water works, and forming environmental standards	Economic regulation Financing Water Resource development Bulk water services
State Water Commissions	Regional	32 independent organisations that are responsible for the exploitation and use of water resources in their respective states, through planning and funding critical water infrastructure projects.	Policy and planning Economic regulation Financing Water basin management Water Resource development Bulk water services Water distribution Wastewater collection
Municipal Water Utilities	Local or Municipal	The entities charged with the most responsibility for providing the population with potable water and protecting the environment from sewage contamination. This is accomplished through the tendering of water infrastructure projects in their respective locations, and the day-to-day	Drinking water quality Environmental regulation Economic regulation

		operation of urban water networks.	Water Resource development Water distribution Wastewater collection Wastewater treatment Drainage

Cultural and social aspects to consider

Several questions arise related to social concern which should be considered when selecting technologies for wastewater treatment infrastructures (UNAM, 2013). These points should be taken into account by water managers as they can have an impact on project planning and development:

- Has the potentially affected population been consulted about the construction of the treatment plant?
- Is the population aware of the need and advantages of a wastewater treatment plant?
- Is there a scheme of citizen participation during the decision process as well as during tendering, construction and operation?
- Will employees be from the local community?
- Is there an education plan for the community (guided visits, museum, social service, other actions)?
- Is there a training plan for employees?
- Is there a response plan for emergencies?

6.1.8. Market overview

Market size

The following sectors are considered as involved in the wastewater generation and treatment:

- Wastewater collection, treatment and reuse
- Construction works for wastewater collection, treatment, drainage and irrigation and reuse
- Hidro-sanitary and gas installations
- Architectural and engineering services

Figure 30. shows the number of companies for each of these sectors in the different Mexican states:

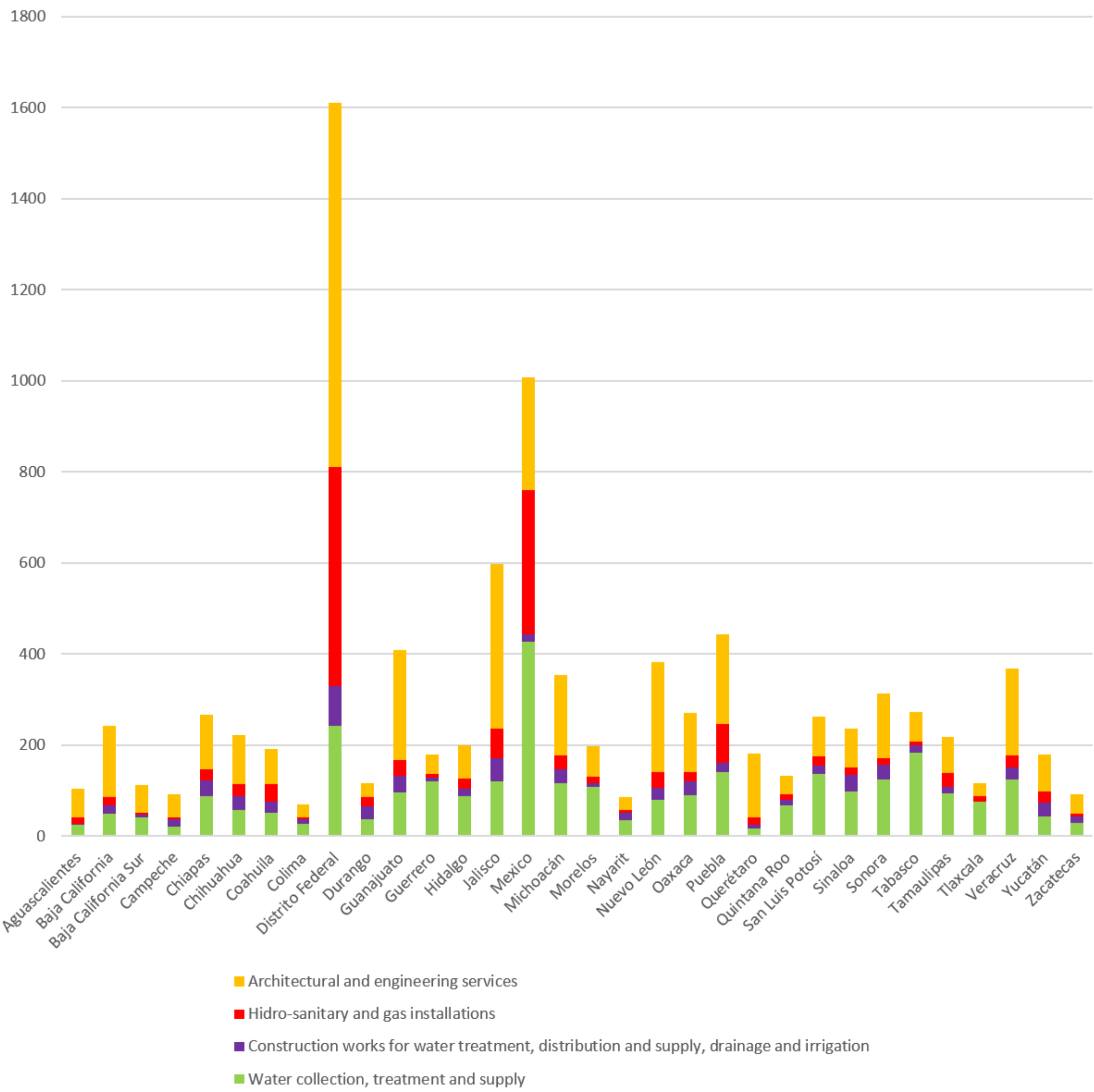

Figure 30. Number of companies involved in different activities within the water sector (based on data from DENUE, http://www3.inegi.org.mx/sistemas/mapa/denue/)

Architecture and engineering services is the sector that stands for the higher number of economic units in all federal entities, although it must be noted that only a percentage of the activity of these companies corresponds to wastewater sector. The following sector in number of companies is Hidro-sanitary and gas installations. Concerning spatial distribution, CDMX, Mexico, Jalisco and Puebla are the states where there are more companies.

Major companies active in the water sector

The previous section provides a general view of the market volume at the different Mexican regions. Table 29 summarizes the main companies working in the water sector in Mexico, providing a brief description and the subsectors where they operate:

Table 29. Main companies working in the water sector in Mexico

Company name	Description	Main sectors active
Abengoa Mexico	Abengoa Mexico is active in various infrastructure sectors, including electricity and water. Their only main water-related project in the country is the construction of the Zapotillo Aqueduct.	Utility water, Power generation
Acciona Agua Mexico S.A.	In Mexico, Acciona is active in the energy and water sectors (amongst others), in design, construction and financing of infrastructure projects. Though their water project resume is not extensive, they can be considered a market leader as they won the contract to build the Atotonilco WWTP, Latin America's largest.	Utility wastewater, power generation
Aquadynamics S.A. de C.V.	Provides water treatment solutions to industrial clients, including oil/water separation and reverse osmosis systems.	-
Aquapro	Provides water treatment solutions to industrial clients, including microfiltration, reverse osmosis, UV disinfection, and membrane bioreactor technology.	Utility water, utility wastewater, Refining & petrochemicals, power generation, food & beverage, pulp & paper, microelectronics
Atlatec S.A. de C.V.	Atlatec is a market leader that specialises in the design, financing, construction and operation of WWTPs countrywide, as well as water solutions for various industrial sectors.	Utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, microelectronics, textiles & tanneries, pharmaceuticals
Ayesa Mexico S.A. de C.V.	Ayesa is an engineering consulting firm that is considered a market leader for water-related projects in Mexico	Utility water, utility wastewater
CH2M	An engineering consulting firm with only one Mexican project on its resume thus	Utility water, utility wastewater

	far, the Atotonilco WWTP. Though the project is the country's largest water infrastructure investment, they cannot be considered a market leader due to a lack of other projects in the country.	
Cobra Instalaciones Mexico, S.A. de C.V.	Firm active in providing desalination solutions and wastewater reuse technologies. They are not as active in Mexico as in other Latin American countries.	Utility water, utility wastewater
Consolidated Water	Consolidated Water is active in the desalination sector in Mexico through the sponsorship of the Rosarito desalination plant in Baja California.	Utility water
Desarrollo y Construcciones Urbanas S.A. de C.V. (DYCUSA)	Large civil construction firm active across many infrastructure sectors. DYCUSA is a market leader, involved in the construction of WWTPs and dams.	Utility water, utility wastewater
Evoqua Water Technologies	Provides water treatment solutions to industrial and municipal clients, including pumps and treatment technologies. Active especially in the refining and petrochemicals segment.	Utility water, utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, microelectronics, textiles & tanneries, pharmaceuticals
FCC Aqualia Mexico S.A. de C.V.	FCC Aqualia's water-related work in Mexico has primarily been in the area of the design and construction of civil infrastructure projects, such as aqueduct concessions, as well as water solutions for the oil & gas industry.	Utility water, upstream oil & gas
Felipe Ochoa y Asociados, S.C.	An engineering consulting firm which is considered a market leader in the Mexican water sector.	Utility water, utility wastewater

Fypasa Construcciones S.A. de C.V.	Fypasa is a market leader that specialises in the design, financing, construction and operation of WWTPs countrywide.	Utility water, utility wastewater
GE Water & Process Technologies México	Provides water treatment solutions to industrial and municipal clients. Market leader in providing advanced technologies to the industrial sector.	Utility water, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, microelectronics, pharmaceuticals
Grupo Carson	Grupo Carso is a conglomerate firm active in sectors as diverse as industry, media, infrastructure and telecommunications. In the water sector it acts as a general civil contractor of large-scale water projects such as aqueducts and WTPs.	Utility water, utility wastewater
Grupo Hermes Infraestructura, S.A. de C.V.	Grupo Hermes is active in the water sector as both a civil contractor and a concessionaire.	Utility water, utility wastewater
GS Inima México	GS Inima is active in the desalination sector in Mexico's Baja California peninsula, through the design, building, and operation of the Los Cabos (built) and Ensenada (under construction) desalination plants.	Utility water
Hi-Pro Ecológicos S.A. de C.V.	Provides water treatment solutions to industrial clients, particularly membrane and membrane bioreactor solutions	Utility water, utility wastewater, refining & petrochemicals, mining, food & beverage, pulp & paper, textiles & tanneries
Impulsora del Desarrollo y el Empleo en América Latina SAB de CV (IDEAL)	Holding company which develops human and physical capital for infrastructure projects. IDEAL is part of the consortium building the Atotonilco WWTP.	Utility water, utility wastewater

Ingenieros Civiles Asociados S.A. de C.V. (ICA)	ICA is Mexico's largest construction firm, with projects across every infrastructure sector. In water they are involved in the financing and construction of large civil works such as aqueducts.	Utility water, utility wastewater
Química Apollo	Provides water treatment solutions to industrial clients. Market leader in the oil & gas and food & beverage segments.	Upstream oil & gas, refining & petrochemicals, power generation, mining, pulp & paper
Regiomontana de Construcción y Servicios (RECSA)	Engineering, construction, and concessionary company active in several infrastructure sectors. RECSA was part of the consortium that won the 2012 MIG contract for San Luis Potosi, which never materialised. It is not a market leader.	Utility water, utility wastewater
RWL Water LLC	RWL Water is a desalination-focused civil engineering firm which is active in Mexico through their role as the project promoter of the San Quintin desalination plant, and their subsequent winning bid to construct it.	Utility water
Suez	Suez is active in the design, construction and financing of WWTPs. It is historically considered a market leader in this area, and the most successful foreign firm in the water sector.	Utility wastewater, refining & petrochemicals
Tecnología Intercontinental (TICSA)	Firm active in concessions for urban water management (in Puebla), WWTP construction and operation, as well as a growing presence in the industrial water treatment field.	Utility water, utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, microelectronics, pharmaceuticals, textiles & tanneries

— CONAGUA investment

PROMAGUA is a national program that channelizes resources from the National fund for Infrastructures to address deficiencies in coverage or quality of water supply, sewerage or wastewater treatment. In parallel, it creates incentives for the participation of the private sector. PROMAGUA supports federal and municipal entities, mainly in towns with more than 50,000 inhabitants. This plan operates in two phases depending on the needs of the municipal entities and provides up to 50% of the initial inversion depending on the case (www.fonadin.gob.mx).

SWOT Analysis

The following sections summarize the strengths, weaknesses, opportunities and threats of the implementation of circular economy in the wastewater sector.

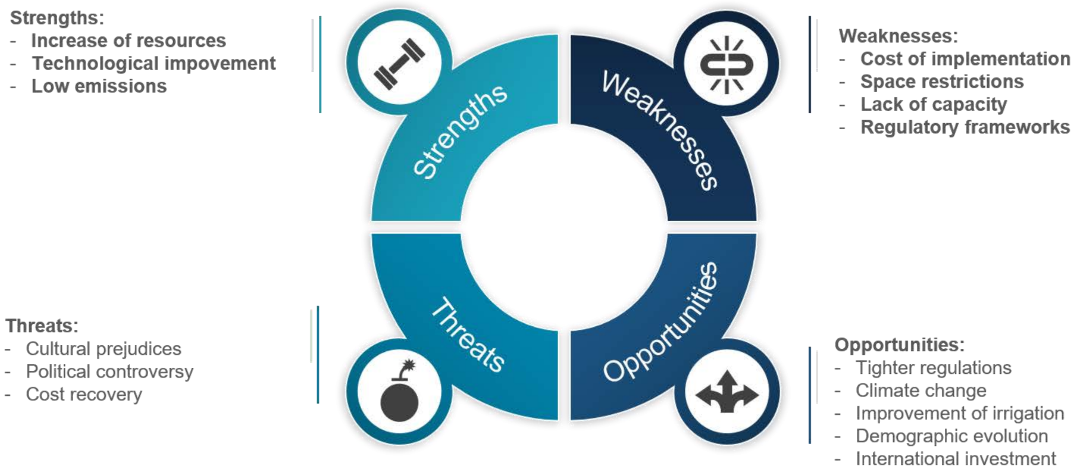

Figure 31. SWOT analysis scheme for circular economy related to wastewater treatment in Mexico

Strengths

- *Increase of resources*: the development of wastewater treatment and reuse of resources available for a large number of applications therefore minimizing the water stress, especially in the driest regions of the country
- *Technological improvements*: Recent research works increase the feasibility of implementation of many wastewater treatment and reuse technologies
- *Low emissions*: Some of the treatment processes (anaerobic, facultative and aerobic without airing) imply low energy consumption and low level of emissions
- Weaknesses
- *Cost of implementation*: some of wastewater treatment and reuse techniques require a significant cost for implementation
- *Space restrictions*: land treatment technologies have space requirements that are not always easy to fulfil

- *Lack of capacity*: some high technology treatment processes are not currently available in Mexico and this fact means that training operators would be necessary before implementing these methodologies
- *Regulatory frameworks*: water regulation establishes tight requirements that can make some of the simple methodologies insufficient to achieve water quality objectives

Opportunities

- *Tighter regulations*: the establishment of more restrictive regulations enhances the introduction of new technologies providing better treatment processes to accomplish the required quality levels
- *Climate change*: climate evolution leads to longer dry periods and more extreme rainfall events. The fact that water inputs become more irregular in time makes it necessary to improve water management approaches and to enhance sustainable techniques. Taking these points into account, wastewater treatment technology and water reutilization stand as a solution with great potential for the near future
- *Improvement of irrigation*: at the beginning of the 90's, National Institute of Ecology estimated that 44.3% of municipal wastewater were used for irrigation without treatment. This fact implied serious damage for the land and aquifers as well as for human health, with specific emphasis on intestinal illnesses. The increase in the number of water treatment plants has partially solved this problem but there is still a long way to go before achieving national objectives in this matter.
- *Demographic evolution*: based on CONAPO (Consejo Nacional de Población, National Population Council) projections, between 2017 and 2030 the population in Mexico will increase in 13.9 million people, although increase taxes will tend to decrease. Moreover, in 2030 approximately 78.3% of the total population will be established in urban areas. Water management must adapt to this evolution and this adaptation implies enhancing sustainable approaches and water reutilization
- *International investment*: Mexico is open to international investment on wastewater treatment and operation. This fact promotes development of new technologies in the country and increase market opportunities in this sector.

Threats

- *Cultural prejudices*: feasibility of water reuse for certain applications can be conditioned by social prejudices and ignorance regarding the treatment processes that water goes through. For instance, the Atotonilco Wastewater treatment construction was closed for 1 year as local farmers sought to disrupt construction as they were against the introduction of treated wastewater on their lands due to their belief that it would result in reduced yield.
- *Political controversy*: As water is a basic need for the population, social opinion is extremely sensitive to new water legislations. Social and industrial interests are not always easy to satisfy simultaneously, and distrust is common amongst the population. Several water laws have found difficulties in their approval during the last years. This fact can have an impact on feasibility of national plans and alter market opportunities.

— *Cost Recovery*: Due to social pressures, it is very difficult for governments to raise the water tariffs to the point that many wastewater treatment operations are not covered by tariffs alone and have to be heavily subsidised.

6.1.9. Key events and conferences

The following table shows the most important conferences and expositions in the water sector during 2019:

Table 30. Main International conferences and expositions within the water sector

Event	Place	Dates	Description
Efficient 2019	Gran Manila (Philippines)	January 13th-16th	International Water Association joins professionals in urban water and wastewater to discuss shared challenges and efficient solutions.
WFES Water	Abu Dhabi (U.A.E.)	January 14th-17th	World event for innovative sustainable energy and clean, efficient technology
WWT Wastewater 2019	Birmingham (UK)	January 19th	Sessions on networks, infrastructure, treatment and biological resources
The WWETT Show (Water & Wastewater Equipment, Treatment & Transport Show)	Indianapolis (USA)	February 20th-23th	One of the world's largest meetings for professionals in the environmental sector
WaterEx World Expo	Mumbay (India)	February 20th-23th	Suppliers of water and wastewater treatment technologies, consultants and municipal leaders
WEX Global 2019	Lisboa (Portugal)	March 4th-6th	Meeting point for water and energy leaders
AWWA/WEF Utility Management Conference	Nashville (USA)	March 5th-8th	Last approaches, practices, procedures, techniques and case studies in public services management

ISH	Frankfurt (Germany)	March 11th-15th	Responsible water and energy management
Aqua Nederland Vakbeurs Gorinchem 2019	Gorcum (The Netherlands)	March 19th-21th)	Water and wastewater market, with more than 300 expositors and 10000 water professionals
Water Philippines	Gran Manila, Philippines	March 20th-22th	Water supply, sewerage, treatment and purification of industrial wastewater
Global Water Summit	London (UK)	April 8th-10th	Water technology, finances and industry future
WIOG NZ Conference	Hamilton (New Zealand)	May 7th-10th	Professionals in water and wastewater sectors
SWAN 2019 Conference	Miami (USA)	May 15th-16th	Leader world centre in intelligent water and residual waters
Aquatech China	Shanghai (China)	June 3rd-5th	Water technology and management. Integrated solutions integrated to Asian water challenges
LET 2019	Edimbourgh (UK)	June 10th-14th	Leading Edge Conference on Water and Wastewater Technologies
Water Leaders Summit	Milwaukee (UK)	June 26th-27th	Main event of the Water Council for local, national and world industry
The Water Expo	Miami (USA)	August 28th-29th	Equipment and technologies in the water sector
Aquatech Mexico	Ciudad de México (México)	September 3rd-5th	The largest exposition in Mexico for processes, water supply and wastewater
One Water Summit	Austin (USA)	September 18th-20th	Sustainable water future
Water New Zealand Conference	Hamilton (New Zealand)	September 18th-20th	Sustainable management, water supply, wastewater and rainfall water management

International Water Conference	Orlando (USA)	November 10th-14th	Technology and latest scientific research

6.1.10. Existing reports/information for further reading

- Global Water Market 2017a. Volume 1: Companies and Markets. Global Water Intelligence
- Global Water Market 2017b. Volume 2: The Americas. Global Water Intelligence
- Low Carbon Business Action in Mexico. Component 1: Mapping of specific needs and gaps and identification of potential partners in Mexico, December 2015.
- Tecnologías y usos de las aguas residuales en México, in Tecnologías sostenibles para el tratamiento de aguas y su impacto en los sistemas acuáticos. Dr. Antoni Escalas Cañellas.
- Agenda del Agua 2030, Comisión Nacional del Agua (Conagua)
- Estadísticas del agua en México, Edición 2018, Comisión Nacional del Agua (Conagua)
- Financing water resources management in Mexico, Conagua.
- Hydrological Policy and Technological Change on technologies applied to the Treatment of Sewage Waters, Journal of Technology Management & Innovation, 2013 (8), special issue.
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- Review of emerging nutrient recovery technologies and other renewable energy systems. Jingwei Ma, Nick Kennedy, Georgine Yorgey and Craig Frear, Washington State University
- Plan Nacional de Desarrollo. Programa Nacional Hídrico, Comisión Nacional del Agua (Conagua)

6.1.11. List of potential partners

The following table summarizes the main companies working in the water sector in Mexico, providing a brief description and the subsectors where they operate:

Table 31. List of potential partners and sectors where they operate

Company name	Main sectors active
Abengoa Mexico	Utility water, Power generation
Acciona Agua Mexico S.A.	Utility wastewater, power generation
Aquadynamics S.A. de C.V.	-
Aquapro	Utility water, utility wastewater, Refining & petrochemicals, power generation, food & beverage, pulp & paper, microelectronics
Atlatec S.A. de C.V.	Utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage,

	pulp & paper, microelectronics, textiles & tanneries, pharmaceuticals
Ayesa Mexico S.A. de C.V.	Utility water, utility wastewater
CH2M	Utility water, utility wastewater
Cobra Instalaciones Mexico, S.A. de C.V.	Utility water, utility wastewater
Consolidated Water	Utility water
Desarrollo y Construcciones Urbanas S.A. de C.V. (DYCUSA)	Utility water, utility wastewater
Evoqua Water Technologies	Utility water, utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, microelectronics, textiles & tanneries, pharmaceuticals
FCC Aqualia Mexico S.A. de C.V.	Utility water, upstream oil & gas
Felipe Ochoa y Asociados, S.C.	Utility water, utility wastewater
Fypasa Construcciones S.A. de C.V.	Utility water, utility wastewater
GE Water & Process Technologies México	Utility water, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, microelectronics, pharmaceuticals
Grupo Carson	Utility water, utility wastewater
Grupo Hermes Infraestructura, S.A. de C.V.	Utility water, utility wastewater
GS Inima México	Utility water
Hi-Pro Ecológicos S.A. de C.V.	Utility water, utility wastewater, refining & petrochemicals, mining, food & beverage, pulp & paper, textiles & tanneries
Impulsora del Desarrollo y el Empleo en América Latina SAB de CV (IDEAL)	Utility water, utility wastewater

Ingenieros Civiles Asociados S.A. de C.V. (ICA)	Utility water, utility wastewater
Química Apollo	Upstream oil & gas, refining & petrochemicals, power generation, mining, pulp & paper
Regiomontana de Construcción y Servicios (RECSA)	Utility water, utility wastewater
RWL Water LLC	Utility water
Suez	Utility wastewater, refining & petrochemicals
Tecnología Intercontinental (TICSA)	Utility water, utility wastewater, upstream oil & gas, refining & petrochemicals, power generation, mining, food & beverage, pulp & paper, microelectronics, pharmaceuticals, textiles & tanneries

6.1.12. Companies and clusters involved in private water sector in Mexico

The main companies involved in Mexican water sector are listed next:

Acciona Group S.A.: large Spanish Company that has an infrastructure business as well as wastewater operations

Alfa Laval S.A.: Swedish company with its main business in heat exchangers, separators, pumps and valves

Atlatec S.A.: Large Mexican company owned by Japanese companies Mitsui and Co. and Tokyo Engineering Cooperation that has an infrastructure business and wastewater operations

C&C Ingeniería y Proyectos S.A.: Small wastewater and water engineering company with many projects in the Mexican wastewater sector

Cobra Instalaciones México: large Spanish company that designs, constructs and operates potable water and wastewater treatment plants

Controladora de Operaciones de Infraestructura S.A.: a large Mexican company that operates and maintains drinking-water supply, conveyance, distribution, treatment and management systems

Fypasa Construcciones S.A.: Mexican company dedicated to design, construction and operation of wastewater and potable water treatment plants

Grupo CARSO S.A.: large Mexican cooperation that designs builds and operates water and wastewater treatment plants. Recently bought 50% share in Spanish company FCC (Fomento de Construcciones y Contratas)

Grupo Casgo S.A.: large Mexican infrastructure company

Industrias del Agua de la Ciudad de México S.A.: large Mexican construction company for water treatment Works, distribution and drainage

Isolux de México S.A.: large Spanish company for the construction, development and detailed engineering, civil works, supply and installation of electromechanical equipment, electrical installation projects, commissioning, maintenance for water and waste treatment plants

Marhnos S.A.: large Mexican construction and infrastructure company

OHL Medio Ambiente, Inima, S.A.U.: large Spanish company for the construction, maintenance and operation of wastewater treatment plants

Proyectos y Desarrollos de Infraestructura, S.A.P.L.: large Mexican construction company

Grupo Proaqua S.A.: Mexican company dedicated to the construction of wastewater treatment plants

Tecnología en Sistemas Ambientales S.A.: Mexican company for the design, construction, operation, supervision, commissioning, equipment, operation, supervision, commissioning, equipment, operation and maintenance of wastewater treatment plants

Sacyr México S.A.: large Spanish construction company

On the other hand, these are the most important entities amongst clusters and associations:

AMEHIDRO: Mexican Association for Hydroelectric power

AMEXA: Mexican Association for Environmental Companies

ANEAS: National Association of water operators and sewage companies

ANNCA: National Association for a new culture of water

CESPEDES: Mexican counterpart of the World Business Council for Sustainable Development and belongs to the CEE (Coordinating Business Council)

CICESE: Ensenada Higher Education and Scientific Research Centre

CCMEX Cleantech Cluster México: environmental oriented cluster based in Puebla

CMP+: Mexican Cleaner Production Centre

COPARMEX: Mexican Confederation of Business Owners

IMAPP: Mexican Institute for Public-Private Associations

6.1.13. Research and academic institutions involved in Mexican water sector

The main research institutions involved in Mexican water sector are listed next:

National Autonomous University of Mexico (UNAM)

TEC of Monterrey

Mexican Institute of Water Technology

Autonomous Metropolitan University (UAM)

La Salle University

Anáhuac Northern México University

National Polytechnic Institute

University of Guadalajara (UdG)

Nuevo León Autonomous University

San Nicolás de Hidalgo Michoacán University

Universidad Popular Autónoma del Estado de Puebla (UPAEP)

Endicott College

Research Centre – Centro de Investigación (CIDE)

College of México

Mario Molina Centre

University of the Americas in Puebla

Engineering Institute

Southern Frontier College

National Institute of Forestry, Crop and Livestock Research

The College of Postgraduates

Autonomous University of Chapingo

University of Veracruz

Environmental Information System

National Research and Environmental Capacity Centre

Centre for Environmental Quality

Annex III: Waste to Energy Sector Trends, Legislation, Policy and the Enabling Environment.

6.1.14. Sector Overview: International

There is a conceptual contradiction between the principles of Circular Economy, and the long-term energy needs that have already resulted in over-dimensioned incineration facilities, for example, without the long-term supply of waste guaranteed for the operation of such facilities.

The juxtaposition of an ever-increasing energy demand and the critical proportions of waste generation will continue to accompany the increasing rates of urbanization the world is undergoing, particularly the developing world, according to a World Bank urbanization report. These pressures can put governments in a very uncomfortable position, being pushed to make capital intensive decisions without an adequate strategic approach or the subject matter expertise to consider the technical, financial and social risks tied to such investments, and the implementation of the appropriate mitigation measures to ensure that waste to energy does not become the standard solution, but rather a piece of the programmatic approach aimed at reducing waste.

Considering solid waste and wastewater treatment as directly related to total waste generation with energy potential, according to a 2018 World Bank report on global waste, the world generates 0.74 kilograms of waste per capita per day, yet national waste generation rates fluctuate widely from 0.11 to 4.54 kilograms per capita per day. Waste generation volumes are generally correlated with income levels and urbanization rates.

Around 130 million tons of municipal solid waste (MSW) are combusted annually in over 600 waste-to-energy (WTE) facilities globally that produce electricity and steam for district heating and recovered metals for recycling. Over the last five years, waste incineration in Europe has generated between an average of 4% to 8% of the electricity and between an average of 10% to 15% of the continent's domestic heat.

Advanced thermal technologies, like pyrolysis and gasification, and biochemical anaerobic digestion systems are beginning to make their mark in the waste-to-energy sector and are expected to increase their respective market shares because of global interest in integrated waste management frameworks in urban areas. Scarcity of waste disposal sites coupled with growing waste volumes and solid waste management challenges are generating a high degree of interest in energy-from-waste systems among policy-makers, urban planners, entrepreneurs, utility companies, etc.

2007 there were more than 600 WTE plants in 35 different countries, including large countries such as China, and small ones such as Bermuda and other Caribbean islands. Some of the newest projects are located in Asia. China is sponsoring a surge in waste-to-energy installations and has plans to establish over 125 new waste-to-energy plants during the following decade.

However, currently European countries are recognized as global leaders in the waste-to-energy movement. They are followed behind by the Asia Pacific region and North America respectively. In 2008, Europe had more than 475 WTE plants across its regions – more than any other continent in the world – that processes an average of 59 million tons of waste per year. In the same year, the European WTE industry had generated revenues of approximately €3.9 Billion.

Legislative shifts by European governments have seen considerable progress made in the region's WTE industry as well as in the implementation of advanced technology and innovative recycling solutions. The most important pieces of WTE legislation pertaining to the region have been the European Union's

1. Waste Framework directive, which establishes a five step Waste Hierarchy, which member states are obligated to implement in their own legislation to move waste management up the Waste Hierarchy.
2. Landfill Directive, which was officially implemented in 2001 which is aimed at minimizing landfilling within the EU to prevent and reduce the negative effects of waste landfills on the environment and human health. The focus is to reduce biodegradable municipal waste going to landfills to avoid the release of methane., a powerful GHG.
3. Incineration Directive, establishing measures to prevent or reduce air, water and soil pollution caused by the incineration and co-incineration of waste, setting emission limits for certain pollutants released to air and water (such as dust, nitrogen oxides, Sulphur dioxide, hydrogen chloride, heavy metals, dioxins and furans, etc.)

In 2015 during the Conference of the Parties ("COP 21") in Paris, 195 countries agreed to limit global warming below two degrees centigrade, to achieve this, certain instruments were required, such as: accelerating the use of renewable energies and increasing energy efficiency mechanisms.

According to figures from the International Renewable Energy Agency ("IRENA"), the regions with the highest share of renewable energies in that year were Asia with 39.7% and Europe with 25.1%, while the region with the lowest participation was Central America and the Caribbean with 0.6%.

Table 32. Global overview of renewable energy capacity and generation of electricity [Source: IRENA]

Region	Installed capacity (MW)	% from total installed capacity
Africa	36.447	1.9%
Asia	779.947	39.7%
Central America and the Caribbean	11.580	0.6%
Eurasia	90.081	4.6%

Europe	493.329	25.1%
Middle East	17.487	0.9%
North America	326.707	16.6%
Oceania	25.926	1.3%
South America	183.185	9.3%

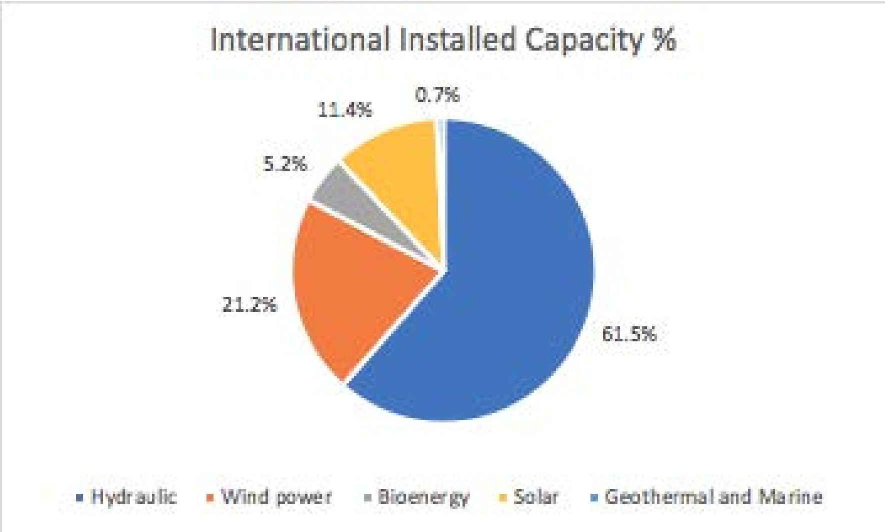


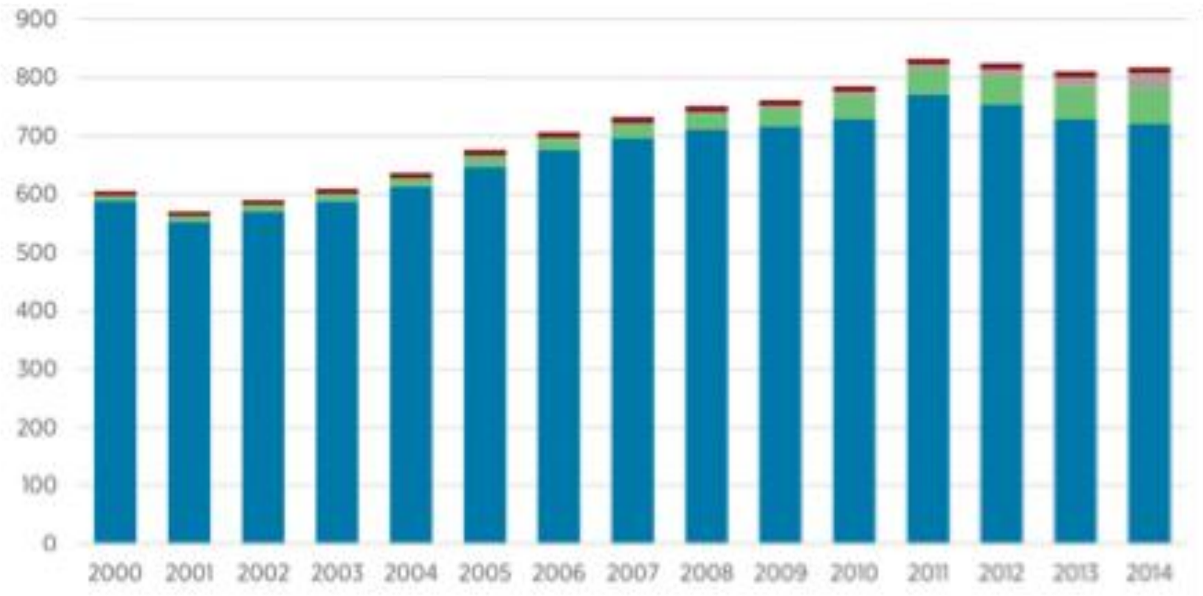
Figure 32. International installed capacity per technology [Source: International Renewable Agency IRENA]

6.1.15. Renewable energies – Latin American context

Latin America and the Caribbean are some of the most dynamic renewable energy markets in the world. At the end of 2015, the generation capacity for renewable energies was 212.4 GW, of which hydropower represented the largest share of the regional total with an installed capacity of 172 GW from large plants greater than 10 MW.

Between 2000 and 2014, the diversity of renewable energies used to generate electricity has increased significantly, as shown in the following chart.

Evolution of electric power generation, 2000 – 2014 (TWh), [Source Renewables in Latin American and the Caribbean, IRENA]



Hydro Bioenergy Wind power Solar Geothermal

Hydroelectric power plays a relevant role within renewable energies in Latin America, improving the economic efficiency and reliability of electrical systems while adding predictability to the generation potential.

6.1.16. The Enabling Environment

Policy and Legislation

In 2014, after an Energy Reform, the Mexican Constitution changed its 25th, 27th and 28th articles allowing the private sector to actively participate in the generation and commercialization of electricity.

Since then, the legislative framework now permits and in fact entices the use of waste, both organic and inorganic, as a power source, exploiting the energy potential of current industrial processes, farming waste and even standard landfills.

The new Mexican legal framework establishes the following to describe renewable power:

Table 33. Mexican legal framework

Document	Objectives	Description
Law for the Use of Renewable Energy and Financing of the	Aimed at regulating the renewable energy source use	Mexican law defines renewable energy as that which is sourced

Energy Transition [Ley para el Aprovechamiento de Energías Renovables y Financiamiento de la Transición Energética] (DOF, 07/06/2013)	and the clean electrical power technologies for uses other than serving the public electrical power consumers	from naturally occurring and naturally regenerating phenomena resulting in processes or materials which are susceptible to being transformed to useful energy, either periodically or continuously.
Electric Industry Law [Ley de la Industria Eléctrica (LIE)] (DOF, 11-08-2014)	Regulates the sustainable development of the electric industry as well as the emission reduction of the public electric service.	This instrument explicitly includes the use of Methane and other commonly existing gases in wastewater treatment, landfills, fish farms, among others (Art. 3, XII-f)
Law for the promotion and development of bioenergy [Ley de Promoción y Desarrollo de los Bioenergéticos (LPDB)] (DOF, 01-02-2008)	Promote the use of bioenergetics as an alternative and renewable energy source	Defines that SENER is the only instance responsible for giving permits to exploit biogas from landfill.
Energetic Trasition Law [Ley de Transición Energética (LTE)] (DOF, 24-12-2015)	Regulate the sustainable use of energy as well as the obligations in terms of Clean Energies and reduction of polluting emissions of the Electrical industry	The fuels obtained from biomass, like the organic fraction of the RSU and the WWTP sludge are considered in the law
Law for the promotion and development of bioenergy [Ley de Promoción y Desarrollo de los Bioenergéticos (LPDB)] (DOF, 01-02-2008)	This law instituted PRONASE as the governing document for the sustainable use of energy in Mexico	PRONASE establishes six objectives, 18 strategies and 69 lines of action, to achieve the optimal use of energy in all processes and activities of exploitation, production, transformation, distribution and consumption of energy.
Regulation of the Electricity Public Service [Reglamento de la Ley del Servicio Público de Energía Eléctrica]	Regulate the Electricity Public Service Law in relation to the provision of said service and the activities planned	It regulates the electrical works for the public service, public lighting and urbanization of splits, supply and sale of electric power, rates provisions and

(DOF, 30-11-2012)	in the Law itself that does not constitute a public service.	facilities destined to the use of electric power
Regulation of the Law for the Use of Renewable Energy and the Financing of the Energy Transition [Reglamento de la Ley para el Aprovechamiento de las Energías Renovables y el Financiamiento de la Transición Energética] (DOF, 04-05-2017)	Regulate the Law for the Exploitation of Renewable energies and the Financing of the Energy Transition.	Establishes policies for net economic benefits, efficient cogeneration, renewable energy generation, and the interaction with the electric network
The General Climate Change Law [Ley General de Cambio Climático (LGCC)] (DOF, 13-07-2018)	Seeks, among other things, to promote the use of the energy potential found in waste, proposing investments in infrastructure meant to minimize and valorise waste and avoid methane emission by the MSW (Art. 34, IV, a).	Guarantee the right to a healthy environment and establish the concurrence of faculties for the application of public policies for adaptation to climate change and the mitigation of emissions of GHG.
Clean Energy Certificates [Certificados de Energía Limpia (CEL)] (DOF, 31/03/2016)	It credits the generation of a determined amount of electrical energy from clean energies.	A certificate issued by the CRE that certifies the production of a specific amount of electricity from clean energy and that serves to meet the requirements associated with the consumption of the Load Centres
Law for the prevention and integral management of waste [Ley para la prevención y gestión integral de los residuos (LGPGIR)] (DOF, 19-01-2018)	The provisions that relate to the protection of the environment in terms of prevention and integral waste management, on national territory.	Applies the principles of valuation, shared responsibility and integral waste management, under criteria of environmental, technological, economic and social efficiency, which should be considered in the design of instruments, programs

		and environmental policy plans for waste management.

The following points describes how these Mexican policies could align to different waste to energy projects in Mexico:

- Law for the use of Renewable Energy and the Financing of the Energy Transition (LAERFTE): Even though there is no direct mention of waste as a renewable source, the law does not explicitly eliminate the sourcing of fuels from landfills; however, it does explicitly state that the Municipal Solid Waste cannot be combusted directly if you wish to have the power output to be considered "renewable" (Art. 1, III).
- Electric Industry Law [Ley de la Industria Eléctrica (LIE)]. It also mentions the energy generated from the thermochemical processing of MSW, like gasification, as renewable; as long as its toxic by-product generation, such as dioxins, remains within the legal limits. (Art. 3, fracción XXII-j).
- Law for the promotion and development of bioenergy [Ley de Promoción y Desarrollo de los Bioenergéticos (LPDB)]. It defines bioenergy as fuels originating from biomass coming from agricultural, fishing, commercial and industrial processes, including microorganisms, enzymes and other by products.
- The General Climate Change Law [Ley General de Cambio Climático] seeks, among other things, to promote the use of the energy potential found in waste, proposing investments in infrastructure meant to minimize and valorise waste and avoid methane emission by the MSW (Art. 34, IV, a).

6.1.17. Governance

Table 34. Mexican governance context

Entity	Level	Description	Roles
Ministry of Energy (SENER)	Federal / National	Responsible for the management of energy, of all the chain value: production, distribution and commercialization.	Policy and planning
National Council on Science and Technology (CONACYT)	Federal / National	Responsible of the promotion of scientific and technological activities, setting government policies for these matters, and granting scholarships	Granting and planning

		for postgraduate studies.	
Mexican Innovation Centres for Clean Energy (CEMIES)	Federal / National	A multilateral initiative that aims to achieve global clean energy technology performance breakthroughs and cost reductions.	Energy security, economic growth and environmental sustainability
CEMIE Bio	Federal / National	Integrated through 5 thematic clusters: Biogas, Bio alcohol, Solid Biofuels, Bio Jet fuel and Biodiesel	Link the efforts of the academic and industrial field with the objectives and goals of the public sector (FSE, 2014).
Green Climate Fund (GCF)	International	Established to limit or reduce greenhouse gas (GHG) emissions in developing countries, according to national programs that aims to develop bioenergetics solutions and other renewable energy projects.	Capture and canalize funds
Ministry of finance and public credit (SHCP)	Federal / National	Creator of the GCF Public Trust	Policy and planning
Ministry of Environment and Natural Resources	Federal / National	President and member of the GCF Public Trust committee	Policy and planning

(Secretaria del Medio Ambiente y Recursos Naturales)			
Secretariat of the Interior (SEGOB)	Federal / National	Public ministry concerned with the country's domestic affairs and member of GCF Public Trust committee	Policy and planning
Ministry of Social Development (SEDESOL)	Federal / National	Member of GCF Public Trust committee	Policy and planning
Ministry of Transportation & Communications (SCT)	Federal / National	Member of GCF Public Trust committee	Policy and planning
Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA)	Federal / National	Member of GCF Public Trust committee	Policy and planning

6.1.18. Cultural and Social Aspects

The cost of waste disposal in Mexico is generally low. On the one hand, waste generators pay low to no fees for waste disposal services, on the other hand, municipalities opt for low cost disposal methods like unmanaged sites or landfills in the best-case scenarios. This means that waste to energy projects will have a limited financial contribution from waste producers, especially in the residential sector. Much of the tipping fees received by waste collectors are paid in weekly cash contributions outside of the formal economy, and these fees will hardly be re-directed towards W2E project operators.

Law enforcement is very weak when it comes to waste disposal in Mexico. The low price of not abiding to the waste disposal regulations, makes it easy for both waste generators and municipalities to avoid investing in appropriate waste disposal technologies. Economical powerful groups are especially strong in avoiding the cost of fines that could result from insensible waste disposal practices. However, these same groups are attracted to invest in sustainable technologies due to the good corporate image that is portrayed when green technologies are implemented in their operations.

Low population density regions in rural Mexico often lack waste disposal services. Given the low budgetary allocation of these regions, waste is often left exposed, creating a health risk. To eliminate bad odours, and free-up space, it is a common practice to burn the waste out in the open, without energy recovery. In addition, low tech agricultural areas tend to burn the dried leaves and stems from harvesting seasonal crops like corn, wheat, beans among others. Such practices pose a threat to the environment and represent a health hazard to the inhabitants.

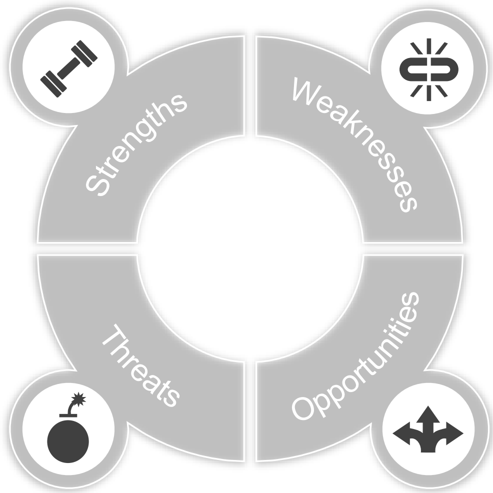
6.1.19. SWOT Analysis

Strengths

- Sufficient regulatory support and guidance to enhance the responsible management of MSW.
- Fiscal, economic and market instruments have been defined,
- GHG Emissions generated by MSW have been estimated, which would serve as a baseline for any results accounting.
- More private sector participation in wastewater treatment and solid waste valorization.

Weaknesses

- Insufficient waste management and wastewater treatment infrastructure.
- Lack of standards for information collection and analysis from the authorities regarding waste classification and measurement.
- High CAPEX and OPEX vs. low resource allocation.
- Low experience and skillset by municipal personnel.
- Low standardized waste sorting capabilities means added cost to run by the private sector.



Threats

- Low certainty in Carbon markets
- Limited public funding to explore market growth.
- Higher cost alternative to other sources of renewable energy,
- Lower apparent appetite for non-fossil fuel alternatives from the new ruling party
- High interconnectivity costs tied to remote generation.

Opportunities

- Private sector interventions to assist the municipalities to comply with buyer-set standards
- Sponsorship by international carbon funds.
- New industrial development clusters considering circular economy from the design to operation
- Solid biofuels sourced from agricultural and agribusiness waste, can be used with existing equipment and infrastructure

Strengths

- Sufficient regulatory support and guidance to enhance the responsible management of MSW.
- Fiscal, economic and market instruments have been defined, adding feasibility to new project developments around the use of wastewater and MSW for power generation.
- Significant budgets have been programmatically allocated to enhance the national water treatment infrastructure having allocated over $20MM USD over the last four years.
- GHG Emissions generated by MSW have been estimated, which would serve as a baseline for any results accounting.
- More private sector participation in wastewater treatment and solid waste valorisation.

Weaknesses

- Insufficient waste management and wastewater treatment infrastructure.
- Lack of standards for information collection and analysis from the authorities regarding waste classification and measurement.
- Some states have below 50% waste collection services, like Puebla, and Baja California Sur.
- High CAPEX and OPEX vs. low resource allocation.
- Low experience and skillset by municipal personnel.
- Understaffed and underbudgeted environmental enforcement.
- Low standardized waste sorting capabilities means added cost to run by the private sector.
- Higher cost of capital than in other regions and increased financial risk.

Opportunities

- Private sector interventions to assist the municipalities to comply with buyer-set standards, and now audited to the third tier in the supply chain by both domestic and foreign buyers.
- Sponsorship by international carbon funds.
- National Carbon funds.
- Commercialization of alternative fuels, such as CNG (Clean Natural Gas).
- Power self-generation to increase operational resilience; connected to grid to sell oversupply.
- New industrial development clusters considering circular economy from the design and need a dedicated service provider to assist with project diagnosis, engineering, procurement and construction (EPC) of a technically sound solution, as well as the financial products to make such solutions feasible.
- Unlike other renewable energy sources, solid biofuels sourced from agricultural and agribusiness waste, can be used with existing equipment and infrastructure: the inclusion of biomass pelletizing into existing thermoelectric generators, cogeneration for the sugar cane industry, among others.

Threats

- Low certainty in Carbon markets
- Limited public funding to explore market growth.
- Higher cost alternative to other sources of renewable energy, if only the energetic benefit is to be considered, not including the diminished GHG emissions from current standard practices, and the revenue generated by the collection and treatment of the waste itself.
- Lower apparent appetite for non-fossil fuel alternatives from the new ruling party which could make the incentives prefer traditional power sourcing in the short term.
- Higher cost of providing purified natural gas equivalent from waste processing than from traditional sources due to biomass sourcing instability and other market inequalities.
- High interconnectivity costs tied to remote generation.

Annex IV: Success Stories

Within the solid waste sector crucial elements are related to the reduction of material inputs as well as to the creation of knowledge which can be gained to envision a future in which circular approaches to resource management is predominant. The following two cases highlight important milestones in this respect.

Box 1. Soild Waste sector successful examples of Circular Economy Initiatives (Guerra Díaz, 2017)

Re-Tek: A European SME, provides reverse logistics and data destruction services for redundant IT equipment. Refurbishing equipment for re-sale or donation to charitable causes, Re-Tek divert equipment from energy hungry recycling processes, extend the life of the asset and minimise environmental impact. Set up initially to work with large original equipment manufacturers, the company now processes 7000 ICT items per month, in a custom built 22,000 ft facility, which, as a result of an extensive investment programme, is now powered by 70% renewable energy. Currently employing 32 people, the company has repair and refurbish expertise and sales channels across all types of IT equipment, including networking and storage as well as handheld, laptops, PCs and monitors.

Re-Tek currently source most of their products from medium to large sized organisations in the UK and Europe and has major clients across all industry sectors including the Financial Industry, Oil & Gas and Pharmaceutical, as well as public sector bodies such as local authorities, universities and the NHS.

Of all the equipment received, approximately 80% progresses to be re-marketed. Only equipment which is completely non-functional, or has no market value goes to conventional recycling partners, and whenever possible, a non-functioning item is harvested for spare parts – thus the resulting landfill is just 1%. This circular economy business model adopted by Re-Tek has been recognised by the Institute for Environment and Sustainability of the European Commission Joint Research Centre (JRC) who recently conducted a site visit to Re-Tek's premises and identified the processes and systems as being best practice.

Reasons for success

- ✓ Culture of entrepreneurship within large industries that pave the way for smaller industries and provide the private sector with lighthouse initiatives for other industries.
- ✓ The change is led from an economic stand point with environmental gains seen as secondary. This results in a substantial reduction in material input that is achieved through these initiatives.
- ✓ Cradle to cradle management strategies are promoted throughout the entire company so that all employees follow the circular economy approach.

Box 2. Generating and sharing knowledge innovation in circular economy

It is widely acknowledged that research and hence innovation approaches are essential to foster circular economy, and this is no different in the solid waste management sector with a particular focus on industry. A global initiative to bring research to the forefront of circular solutions is the *The Greening of Industry* platform, which is an international network of professionals from research, education, business, government and civil society organizations that are focusing on the issues of industrial development, environment and society that is dedicated to building a sustainable future. The Greening of Industry Network brings together people of various backgrounds (professionally and geographically) to meet, exchange ideas and develop strategies. With coordinating offices in various countries (including Mexico), participants engage from more than 50 countries to respond to the challenges of sustainable development. Through linked conferences, publications and communications, the network creates new relationships, visions, and practices for sustainability and circular solutions. Each year a high-level international conference is held in Mexico with the participation of start-ups, large transnational business, governments as well as researches with space to create alliances between the public and private sectors and to promote circular approaches. These yearly events position Mexico broadly within the circular economy movement.

Reasons for success

- ✓ Shows concrete examples of networking activities that are able to foster circular economy in Mexico
- ✓ It is the only conference of its type to bring together such a broad range of stakeholders in the solid waste industry.
- ✓ The conference in 2018 in Mexico had a first promotion for a shift towards a circular economy.
- ✓ New strategies and vision papers are produced in the lead up to the conference

6.1.20. Success stories in wastewater management

Circular solutions in a country with high water stress is crucial. This is why water reuse is of high importance to mitigate the effects of climate change. Furthermore, wastewater can be reused to mitigate climate change through aiding in energy production. The following two examples provide successful cases of how circular solutions have been employed in the wastewater industry in Mexico.

Box 3. Integrated wastewater management plan and wastewater reuse in San Luis Potosí (The World Bank Group, 2018)

The Tenorio wastewater treatment plant is the largest treatment plant in the metropolitan area of San Luis Potosí. The treatment plant treats 45% of the total wastewater generated by the city. The wastewater after treatment is used for cooling of a nearby thermal power plant, agricultural irrigation and environmental enhancement. Of the innovative aspects of the project the following main points can be highlighted: i) the multi-quality use of the treated wastewater to meet the different end users' needs; and ii) the contractual agreement with the industrial user that ensures constant revenue and enhanced financial sustainability of the project. Other environmental, social and economic benefits of the project were also considered. For example, the treated wastewater is of higher quality than the untreated wastewater previously used by farmers. This has increased agricultural production and has allowed farmers to diversify or switch to higher value crops. Another example is the decrease of gastrointestinal and skin diseases rates in the area that was previously irrigated with untreated wastewater.

Reasons for success

- ✓ Economic saving of €9.7 million in six years have been achieved as the treated wastewater is 33% cheaper.
- ✓ Revenue stream from the treated wastewater fees covers almost all operation and maintenance costs in the waste water treatment plant. An example almost unheard of in international cases of wastewater reuse.
- ✓ Public, farmer and industry acceptance of the alternative water sources and paying the corresponding tariffs for the water use.

Box 4. Wastewater reuse with energy recovery: Atotonilco WWTP (CONAGUA, 2011[34])

The Atotonilco wastewater treatment plant, designed, built and operated by the Aguas Tratadas del Valle de México (ATVM) Consortium, which included an international collaboration between European and Mexican partners.

The wastewater treatment plant is the largest in the world, with a nominal average treatment capacity of 35 m3/s and a maximum of 50 m3/s, including the final discharge of the solid waste and sludge generated. The plant located in the state of Hidalgo, Mexico, and over its first year of operation it has complied with all the required effluent quality standards in 100% of the samples taken.

The project received an investment of approximately €560 million. The plant is also equipped with a cogeneration system that takes advantage of the biogas produced during digestion, enabling maximum energy savings. The plant is able to treat 60% of the wastewater generated in Mexico Valley resulting in an equivalent of 12.6 million people. The treated wastewater is reused for agriculture and irrigation, as well as making it possible to change restricted crops to unrestricted, among other benefits.

The Atotonilco treatment plant also contributes significant environmental benefits to the region, by cleaning up the Tula riverbed and helping to restore the environmental aspects of the Endhó dam. The plant also co-generates 60% of all its energy requirements.

[34] http://calderon.presidencia.gob.mx/2011/10/con-la-ptar-san-pedro-martir-la-ciudad-de-queretaro-trata-todas-sus-aguas-negras/

Reasons for Success

- ✓ The plant has shown a great collaboration effort between Mexican and European (Spanish, Danish) companies working in unison to achieve a very complicated goal.
- ✓ After a difficult start, the benefits of the plant were communicated to the local population which allowed the water reuse acceptance to increase.
- ✓ The consortium built local roads and protected a number of plants and animals in the local region through the sanctuary that was set up. Enabling visitors to learn about the local plants and animals.
- ✓ Treated waste water is used for agricultural purposes and green space watering, reducing the use of freshwater resources and thus saving economically and environmentally for the end users.

6.1.21. Success stories in waste to energy

Waste is an important raw material which can be used in an efficient manner to mitigate climate change and produce energy, we have included below successful cases of circular approaches in the waste management sector.

Box 5. Bio digestion of urban solid waste in Atlacomulco (GIZ México, 2018)

The municipality of Atlacomulco has a population of 93,718 inhabitants, which generates 0.96 kg of solid urban waste with a daily final disposal of 90 tons. To reduce the final disposal of this waste, the municipal authorities have started a waste separation program from the source, separating organic from inorganic, into recyclable and non-recyclable wastes. The organic waste collected corresponds to 50% of the total volume of solid waste, of which 30 tons are delivered daily to the Atlacomulco anaerobic bio digestion plant, where biogas is generated. Bio digestion forms part of the municipalities integrated management system for urban solid waste which includes the disposing and managing of the waste in a specific cell. In the process two fermentation processes take place, one for solid fermentation and one for liquid fermentation. This plant produces biogas as a fuel for electricity production and organic fertilizer as sub-product. In 2015 2400 m3/day of biogas as fuel were produced and in that same year 1,752.091 kWh/year of energy was produced that was used to power the municipalities energy requirements.

Reasons for Success

- ✓ The Ministry of the Environment worked closely with the Atlacomulco City Council for the valorisation of the solid waste fractions and implemented training and advisory courses in this area to continue with the successful implementation of the plant.

Box 6. The cement industry: co-processing (GIZ México, 2018)

Since 2012 Cemex has introduced co-processing of the inorganic fraction from urban solid waste (FIRSU) into its processes. It is a process which is based on the separation of materials from sanitary landfills. FIRSU is a green fuel composed of paper and paperboard (50%), plastic (32%), textiles (10%) and Wood (8%). FIRSU can be used as a substitute to fossil fuels, as well as reducing the CO2 emissions. In the cement kilns, which reach temperatures of up to 2,000 degrees Celsius, they operate with an advanced control system and have a powerful gas neutralization system for solid waste that no longer has the possibility of being recycled. This waste can be used as an alternative fuel in the CEMEX cement kilns. The results have indicated that the co-processing of FIRSU is an environmentally-friendly option, since the disposal of this fraction in landfills is avoided and also the use of non-renewable resources in cement kilns decreases. As such, CEMEX was the first company to obtain the Clean Industry certificate granted by the Federal Attorney for Environmental Protection (PROFEPA), in addition to having ISO 14000 and ISO 9000 certifications.

Reasons for Success

- The involvement of the research industry (UNAM) and the CEMEX with the financing of the central government lead to positive results and a resultant full implementation.
- The co- processing of FRISU done my CEMEX in 2017 mitigated 325 thousand tons of CO2eq.
- FRISU has a lower carbon impact than primary carbon fuels typically used in cement production and hence contributes to the reduction of CO2 emissions in the cement production process.

Annex V: Market Opportunities in Circular Economy in Mexico (PPT)

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