Master Thesis Research

A Circular Model to Improve Waste Management in Mexico City´s Residential Areas

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Abstract

Waste generation issues in Mexico City, high volumes, and not enough disposal facilities for them have become a problem that governments alone cannot solve, and consequently local communities have to be involved in the transformation. Of course, the waste management problem is complex and involves several factors, among them, insufficient waste collection system represents one of the barriers for an effective waste management. Thus, this research project attempts to answer if a circular economy approach can become a solution by utilizing *in situ* organic waste for energy generation through an anaerobic digester, reducing waste volumes while doing so, in a residential area in Mexico City as showcase.

The research followed a mix-research method approach which was based on literature review, interviews, and a survey. The secondary data sources provided information about previous experiences and served to construct the analytical framework of this research. The primary sources of information provided insides to better understand the necessities and involvement of local community as well as regulations and requirements for the technology´s installation. As part of the feasibility study, an organic waste generation study was carried out by following standards and procedures defined by the Mexican regulatory framework. The organic waste generation procedure involved the participation of the residential area´s inhabitants.

The findings section shows which technology might suit the conditions of the residential area used as showcase and develops on the operation and maintenance it requires. The main characteristics needed to develop a circular business model is also presented. The business model is described with detailed information to motivate inhabitants or even investors, it includes costs of materials and building of the technology, budget management, financial benefits in terms of utility bills, particularly on electricity and the potentials organic waste has as energy generator. However, certain barriers were also identified mainly related to budget limitations and energy supply. To finalize the findings section, the influence that local communities can have as a driver to impulse initiatives of these characteristics was analyzed during the organic waste generation study and the responds rate of a survey conducted with inhabitants of the residential area. In both elements of this research the inhabitants showed interest by participating actively.

The thesis ends with the conclusion, presenting the characteristics considered that can build an initiative capable of reducing waste generation volumes, as long as the main barriers, namely, financial issues and supply, are successfully addressed. Furthermore, in this section, a series of recommendations are given derived from the barriers found, which from the researcher´s point of view, would enable a successful initiative.

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List of Acronyms

BAT	Best Available Technologies
CBM	Circular Business Model
CFE	Comisión Federal de Electricidad (Federal Electricity Commission)
FIDE	Fideicomiso para el Ahorro de Energía Eléctrica (Trust for Electricity Saving)
kWh	Kilowatts per hour
LEI	Local Energy Initiative
MSW	Municipal Solid Waste
MXN	Mexican currency
SEDATU	Secretaría de Desarrollo Agrario, Territorial y Urbano (Agrarian, Territorial and Urban Development Secretaryship)
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Environment and Natural Resources Secretaryship)
SSA	Secretaría de Salud (Health Secretaryship)

1. Introduction

The structure followed for the development of this thesis begins with introductory information (Chapter 1), presenting a background which provides a problem and motivation of the research, following with the objective of the thesis with the corresponding research question and sub-questions.

1.1. Background

The waste management system of Mexico City is not sufficient to meet the collection and treatment requirements of the amounts of waste generated, for instance, the city and its metropolitan area only has two garbage dumps, with the risk of being overflow, causing various health and pollution related problems. In addition, the constantly growing population, will only increase the impacts mentioned. (Godoy, 2012). The amounts of waste generated every day in this megacity are very high, Mexico City's households and businesses produce 12,893 tons per day of solid waste (SEDEMA, 2015, as cited on Guibrunet, et al., 2017), leading the city to a constant challenge of its waste management. On the other hand, at international level, the world is now setting its view in terms of sustainability standards at all levels of human life, from consumers to producers. Even further, as mentioned by Hettiarachchi, et al., (2018: pp 1), "the same large volume of MSW that has been generated can become a steady supply of resources, if recovery options are prioritized", this can be facilitated if successful waste management systems could be implemented. In fact, large amounts of waste have several implications, health is at risk when low levels of MSW[1] collection are observed, and environmental risks, jeopardizing the environmental quality, for instance greenhouse gas emissions as a result of dumping activities in open air conditions of MSW.

[1] Municipal Solid Waste in Mexico City includes several strategies such as minimization in source, recycling, reuse, thermal treatment, final disposition, among others. The most abundant material in waste in Mexico City is organic (49.5 %), while recyclable material composed by cardboard, paper and plastics has an average value of 24%. (Durán Moreno et al., 2013).

In contrast, households entirely depend on the local and unique supplier of electricity in the country, a state-owned company. The centralized electricity provision, added to the inefficient waste management system can be considered as an opportunity for an *in situ* waste transformation into electricity. By doing so, waste management problem could be improved while simultaneously open up an alternative to reliance on the unique electricity supplier in the country. Therefore, the research focuses on the feasibility analysis of an initiative that aims to provide a solution to the high volumes of organic waste generation and the electricity reliance on one supplier. Furthermore, the research analyzes if local inhabitants can become a driver to implement an energy initiative of this characteristics.

1.2. Research Questions and Objectives

The objective of the research is to present an initiative that can reduce waste volumes in Mexico City´s residential areas. This leads to the following research question:

- What are the main characteristics of an initiative that successfully reduces waste generation in Mexico City´s residential areas by generating energy through a circular model?

The main research question is subdivided in four different sub-questions:

- What are the main drivers and barriers of a circular model for a waste reduction initiative?
- What technology might be suitable for the residence serving as show case in this research?
- What are the main characteristics of a circular business model for stakeholders?
- How can self-organization be a driver to implement Local Energy Initiatives at a residential scale?

Casa de Campo residential area in Mexico City covers the characteristics needed to carry out the research and to identify answers to the questions presented above, for this reason it was used as showcase for this thesis. The selection criteria applied to choose it as showcase are described in section 3.4.

1.3. Thesis Outline

Chapter 2 presents the theoretical background, where the concepts of Self-organization and Local Energy Initiatives are defined giving the reader an overview of the research context, the existing research in the three core aspects, namely, (i) Circular Business Model, (ii) Drivers and Barriers of the decentralization of electricity production from organic MSW, and (iii) Best Available Technologies (BAT) for waste to energy, is presented. In addition, three real waste to energy cases are presented as part of the potentials addressed in this research.

Chapter 3, describes the strategy followed for developing the research, presenting the methodology followed for data collection and data analysis, and deepens on the showcase selection, briefly mentioned in the last paragraph of the introduction.

Findings are then presented on Chapter 4, developed with information collected from interviews and surveys, as well as literature review. The thesis is finished with a conclusion and recommendations (Chapter 5) which summarizes the findings and answers the research question.

2. Theoretical Background

This section presents the interrelations between Self-Organization and Local Energy Initiatives (LEI´s), to implement energy projects in a successful way, which is the objective of this research. Furthermore, three cases of organic waste treatment for energy generation are described and three core aspects are developed to give a better insight of the characteristics of the research, these are, Circular Business Model, Drivers and Barriers, and Best Available Technologies.

2.1. Self-organization as a promising way to implement Local Energy Initiatives

A potential solution for the waste management system will need the participation of local society, not only the institutional stakeholders as mentioned above, but also inhabitants of *Casa de Campo* residential area; self-organization is key, and it refers "to the process by which individuals organize their communal behavior to create global order by interactions amongst themselves rather than through external intervention or instruction". (Willshaw, 2006). Other definitions of self-organization suggest that it is a mechanism in which a trend appears at the system's global level solely as a result of various interactions among the system's lower-level components. The rules that define how the system's components communicate are implemented using only local data, with no relation to the global pattern. (Yates, n.d.), or as a concept that describes the shifting relationships between citizen groups and institutional stakeholders in various fields, including sustainability and energy transitions. (Hasanov & Zuidema, 2018).

Self-organization has a critical role in connecting the three elements analyzed on this chapter, for instance, stakeholders related to legal issues have to be involved in the selection of possible technologies to be able to deal with legal policies that can present barriers for implementation. On the other hand, stakeholders developing a circular business model will have to know the functions and requirements of possible technologies as well as any financial requirement to present an attractive circular business model. Given the objective of reducing waste through a circular model that converts organic waste to energy, self-organization will be associated to what Hasanov and Zuidema (2018, pp. 86) define with the term, local energy initiative (LEI), as an early-stage development citizen-led, decentralized energy project.

Generation of energy using organic residuals as a way to reduce waste volumes is the aim of the research and, as mentioned above, this relates to what Hasanov and Zuidema define as Local Energy Initiative Projects, referring to the potential for grassroots initiatives with a clear and strategic emphasis on energy concerns to transform energy structures. LEI´s are, in general, a collection of numerous types of societal actors working in various institutional contexts, unified by a variety of goals that are not always linked to energy. LEI´s are linked to small, locally based activities that strive to have a larger administrative and organizational effect on state or municipal planning and growth issues. (Hasanov and Zuidema, 2018).

Furthermore, LEI´s emerge due to various factors, most of the research relates these initiatives with activism within communities and decentralized actions, which enables local collective actions. If there is a growing number of LEI´s, it is due to the social acceptance and the awareness in renewable energy amongst people. Even though LEI´s are as the name indicates, local, this type of initiatives collect aspects that are external to the community, for instance, dependence on an energy supplier and the quality offered, technological advancements, or consumers demand for green energy, to name a few. (Hasanov and Zuidema, 2018). To describe successful LEI´s, both internal and external factors should be taken into account and how they interrelate and impact each other, understanding the mechanisms that lead to their different functions. (Hasanov and Zuidema, 2018).

LEI´s have taken root as a very effective way to innovate in the energy system, particularly electricity production. (Arentsen and Bellekom, 2014).

As mentioned, the participation of local society is essential, it will lead to self-organization features in the neighborhoods, this is related to informal or semi-formal activities including various types of community action, social engagement associated to constructive civic engagement, leading to the formation of coalitions with municipal institutions. (Hasanov & Zuidema, 2018). Although, significant issues related to trust or previous experiences of residents and local communities may arise and must be taken into account on every project and initiative planification phase. Considering that trust in the people leading the project is key for a transition movement. (Hossain, 2015).

In addition, both Self-Organization and Local Energy Initiatives relate to bottom-up approaches, which in the past years have acquire popularity, particularly because of people´s interest in transforming their communities or growing awareness regarding environmental endangering.

2.2. Local Waste to Energy Generation Cases

The cases described in this section do not have deep similarities with Mexico City´s characteristics (developing countries context, geographical extent, population and other scale factors), however, the purpose to present them here is to provide a view of the potentials that waste treatment initiatives bring for reducing waste volumes with particular attention to the benefits of implementing waste treatment initiatives as an effective way to generate energy in various forms. We refer to the cases of Vietnam, New York and Sweden.

2.2.1. Vietnam

Vietnam´s generation of municipal solid waste, which in its majority is food waste, is growing rapidly together with a growing urbanization. While this waste is treated mainly by landfilling (not the most environmentally friendly technique), the potential of implementing anaerobic digestion for treating the waste has been studied and considered, given that is a better treatment from an economic and ecological point of view, while being a promising option for energy recovery and mitigate energy shortages. However, Vietnam government has discarded the option due to lack of information, data, and experience. (Nguyen et al., 2014). In spite of this, the anaerobic digestion has been studied in Vietnam and one of those studies is the one by the University of Southampton who developed an energy model called Aspen Plus. In the following paragraphs some details of the modelling of the Anaerobic Digestion are provided:

“Feedstock is fed to a digester in digester ponds, where digestion takes place in the absence of oxygen. The gas generated during the digestion process (raw biogas) is treated to minimize H2S levels and avoid mechanical corrosion before being fed to the CHP and boiler for heat and electricity generation, or to a biofuel upgrade plant. To meet on-site energy needs, both thermal and electrical energy are required; surplus energy is used for off-site purposes. Where the requirement for heat for internal use exceeds the amount of heat generated by the CHP, a boiler unit is used to compensate for the shortfall. Carbon dioxide and undesirable compounds are isolated from raw biogas in the upgrade facility, resulting in purified biogas with a structure that satisfies the requirements for vehicle fuel or natural gas”. (Nguyen et al., 2014).

Two scenarios where run, scenario 1 showed that the amount of energy provided by the CHP unit in the form of heat is roughly two times that of the electricity generated. This reflects the fact that the production of heat from CHP units is about 65 %, while it is around 35 - 43 % for electric power. This means that the electricity generated could contribute to a 4.1 % of Vietnam´s total electricity demand in 2025. Scenario 2 showed the efficiency regarding transportation, as biogas generation can be used for fueling trucks, buses, etc. In 2014 some estimations showed that fuel requirement by 2025 will increase to 30 million tones, so biogas can replace 4.75 % of daily fuel use. (Nguyen et al., 2014).

This illustrates that if organic waste is separated from municipal solid waste, it can become an important source of energy, and it can be achieved through changes in people´s behavior by learning the basics of waste separation (this is of course, assuming that everyone “does the right thing”), helping authorities get the organic waste to feed the digesters. Anaerobic digesters also provide economic solutions on the mid-long term, dealing with increases in energy supply, waste disposal, landfill spaces and environmental impacts. (Nguyen et al., 2014).

2.2.2. New York

The American city produces 14 million tons of waste every year, and the city spends $400 million dollars to ship the waste to the country´s incinerators and landfills in South Carolina. Similar case to the international trade in which the UK sends waste to the Dutch city of

Hengelo for incineration. Former Mayor Michael R. Bloomberg began a program in 2013 to achieve some sustainable goals, and one of them was to reduce greenhouse gas emissions from municipal solid waste, these efforts have continued in the precedent administration with Mayor Bill de Blasio. (Rueb, 2017). These efforts need the citizens' participation to make the program succeed, as Ron Gronen, city´s deputy commissioner of recycling and sustainability mentioned, "Without the citizenry of New York, I don't think our team could have gotten our program off the ground".

Starting in 2013, the city provided households with buckets to collect organic waste, and in 2016, 23,000 tons of organic waste were collected from households, schools., institutions and drop-off points. Neighborhoods started to adopt the program and, in the ones, where there are difficulties for trucks to pick up waste, the city expanded the number of drop-off points. (Rueb, 2017).

In 2012 a testing program took place Newtown Creek Wastewater Treatment Plant in Brooklyn, where commercial food waste was added to some of the tanks in the plant to produce higher levels of methane gas, since then, the plant´s biogas production has increased 17%. Furthermore, the utility National Grid planned an investment of $30 million dollars in a system that gets vapor and carbon dioxide, as well as filters chemicals that are flushed into the sewer system. (Rueb, 2017).

Currently, a small group of National Grid customers can get heat for warming their homes with the gas made from the plant. However, only a small part of the city´s organic waste is transformed into biogas, but programs are still running to reach a day where homes and transportation can run with biogas from organic waste. (Rueb, 2017).

2.2.3. Sweden

Not even one percent of household waste goes to landfills in Sweden, it goes to the thirty-four waste to energy power plants in the country, which is known for notably reducing the amounts of waste that finds its way to landfills. From the total generation of household waste, 49 percent is recycled, while other 50 percent is incinerated in power plants. What this initiative has generated for the country is impressive, given that a small portion of Sweden´s power supply comes from household waste, less than 10 percent, however, most of the heat during cold seasons is supplied by waste. (Yee, 2018).

Of course, one of the advantages, as mentioned in the article, is that “along with reducing landfill, using waste as an energy supply also reduces burning fossil fuels and shipping them around the world using even more fossil fuels for transportation, furthermore, using waste to generate energy is a reasonable short-term solution. (Yee, 2018).

The biogas produced in one of the power plants in Sweden, is currently running over 200 buses in the country, also taxis as public transportation goes, private cars and even trash collection trucks are also being fueled by the biogas generated from waste. (Yee, 2018).

The implementation of the strategies mentioned in the three cases presented was only possible with a previous planification and approvals from local governments, institutions and inhabitants of the cities and communities. A Circular Business Model contains this information for an effective and further planification.

2.3. Circular Business Model

A Circular Business Model (CBM) is a key lever for the implementation of circular economy, which is an economic system in which resource input and waste, emission, and energy leakages are minimized by cycling, extending, intensifying, and dematerializing resources and energy loops. (Geissdoerfer, et al., 2020). Even further, taken from Mentink´s research work (2014), he mentioned that “CBM should be regarded as a subcategory of Business Models (BMs) which fit in an economic system of restorative or closed material loops. This entails that a CBM does not need to close material loops by itself but can also be part of a system of BMs which together close a material loop in order to be called circular”.

Another definition of the CBM is the one provided by Reim at al., 2019 in Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research: “A business model in which a focal company, together with partners, uses innovation to create, capture, and deliver value to improve resource efficiency by extending the lifespan of products and parts that thereby realizes environmental, social, and economic benefits”.

To plan and further implement a waste management program, captured in the CBM, it is needed to evaluate the waste generation and its characterization, as starting point, making the identification of the information available of high importance, as Olay-Romero et al., 2020 mentioned, “Since gathering and processing municipal waste information involves a substantial effort, it is important to identify what information may be available and what parameters are needed to evaluate municipal waste, especially in developing countries”. Organic material is one of the main disposed materials found in households, which can be utilized for electricity generation.

This information will become part of the CBM, which aims at highlighting the attractiveness of transforming households wastes into circular resources. For instance, where waste can be reduced, while electricity can be generated. For that it is important to understand how circular business models are conceptualized.

Circular economy with a business view is used as a guideline for business model development. Even though this research is not aimed for a profitable business, it is important to state that for the CBM, a circular economy approach will aim to increase resource efficiency by closing energy and resource loops whilst gradually closing energy and resource flows. (Pieroni et al., 2019a, p.201, as cited on Geissdoerfer, et al., 2020).

The CBM aims to present the financial information and long-term benefits, as well as legal policies and regulations to make the initiative attractive and engage all the stakeholders[2] involved. It seeks to be as transparent as possible about any barrier that could hinder the development of the initiative. An introduction of the barriers is presented in the following sub-chapter.

Regarding legal policies and regulations, in Mexico, there are instruments that regulate the management of waste, involving generators, transporters, and those who process them. Some of these instruments, are Ley General para la Prevención y Gestión Integral de los Residuos

[2] The stakeholders are the household owners, local government, and administrators of the residence. In the case of administrators, Casa de Campo residential area as in many others in Mexico City, has a group of people that form a committee which are inhabitants of the residential area, together with an administrator which is not an inhabitant of the residential area and acts as connection with public authorities as municipality or local government for regulation means or any other aspects which need to be taken care of for the residential area to operate.

(General Law for Prevention and Integral Management of Residuals), Programa Nacional para la Prevención y Gestión Integral de los Residuos (National Program for Prevention and Integral Management of Residuals) and state and municipal programs of prevention and management of residuals. The so called, primary separation programs, enable the separation of MSW in organic and inorganic residuals. (SEMARNAT, 2015).

The following table, shows the main institutions and authorities involved with waste management in Mexico and their roles and responsibilities:

Table 1 : Main Authorities and Institutions (SEMARNAT, 2015)

Institution/Authority	Roles and Responsibilities
Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)	Elaborate policies and strategies for environmental control
	Norm and fiscalize the environmental regulatory framework
	Coordinate the national programs for environmental management
	Promote the creation of infrastructure (together with SEDATU)
Secretaría de Salud (SSA)	Elaborate policies and strategies for sanitary control
	Norm and fiscalize in health issues
	Elaborate plands for prevention of risk when managing MSW
	Coordinate national programs for environmental sanitation
Secretaría de Desarrollo Agrario, Territorial y Urbano (SEDATU)	Promote the creation of infrastructure (together with SEMARNAT)
Other Secretaryships	Supoprt MSW management in its respective areas (turism, industry, fishing, energy and mining, transportation, household and other)
	Regulation of MSW management in its respective areas
Local Goverments	Management of MSW: sweeping, collection, transfer and final disposition
	Formulation of local framework
	Aplication of sanctions for not compliance with MSW management policies
	Formulation and implementation of mandatory fees for public services

A very important topic to cover in the CBM is insurance. The technology will most likely be a rudimentary adaptation of an industrial anaerobic digester, meaning that people will have to operate it, both for feeding and maintenance purposes, exposing them to any failure the technology may have, which could jeopardize their health. Furthermore, the technology will be located inside a residential area which exposes not only operator but also inhabitants to problems caused by any performance problems with the technology.

The insurance companies AXA, Chartis Mexico, GMX, Inbursa, and Zurich offer products which cover a series of activities that refer to what is mentioned above. For the purpose of this research, the activities mentioned are the ones that best fit the installation of an anaerobic digester, e.g., possession and maintenance of social facilities and Possession and maintenance of sanitary facilities. Additional coverages can be added to the insurance, for instance, Union, mixture and / or transformation of products and environmental pollution. (AXA, 2020).

2.4. Drivers and Barriers for the implementation of a Local Energy Initiative

The poor collection and recycling culture in Mexico appears as one of the main obstacles for implementing circular models in households, social participation is needed as a driver to engage people in activities as recycling. Social participation has been defined as "…the person's involvement in activities that provide interaction with others in society or the community". (Levasseur et al., 2010, p.7, as cited on Nivestam et al., 2021).

Even in a smaller scale, like households or a specific residential area, to begin an implementation of waste management it is needed an increase in the coverage of the collection services and to improve the conditions of the disposal sites. (Olay-Romero, et. al, 2020). The use of solid waste management metrics simplifies decision-making on many levels: it is a useful tool for diagnosing one of the schemes to be applied, and it can serve as the foundation for a continuous tracking protocol to guide technological progress and recognize opportunities and policy adjustments. (Bertanza et al., 2018, ElSaid & Aghezzaf, 2018, as cited in Olay-Romero et al., 2015).

Part of the circular model feasibility research of this thesis is the efficient utilization of the waste generation, for that, part of the research also focuses on biomass and waste as fuel for energy generation. As attractive as this sounds, the concept of self-generation of electricity has a major challenge, considering that Mexico, is a country where electricity has only one supplier (Comisión Federal de Electricidad). On the other hand, the country´s current trend in electricity generation indicates that having small sources of generation, especially by clean energy sources, will be the best practice to produce electricity. (Fideicomiso para el Ahorro de Energía Eléctrica, 2021). This trend points towards distributed generation, that is, the development of small sources of generation located as close as possible to the consumption center, preferably from clean energy sources (descentralization). As established by Ley de la Industria Eléctrica (Electricity Industry Law), distributed generation is the generation of electrical energy that is carried out by an owner or possessor of one or more power plants that are interconnected to a distribution circuit that contains a high concentration of power centers, and that do not require or have permission to generate electricity. (Fideicomiso para el Ahorro de Energía Eléctrica, 2021).

An important specification of contracts with CFE (Federal Electric Comission), is that there is no regulation that obliges users to consume electricity from CFE, this means that anybody can generate their own electricity. However, if there is a surplus on this generation it will pass to CFE´s grid. On the other hand, if the generation is not enough, the extra electricity needed will have to be provided by CFE, as the company owns most of the electric grid in the country.

The lack of waste separation is a big issue which roots are in the low social participation, which is why involvement of the community is a key factor of this research and will be discussed in section 4. The shortage of collection centers to reuse and recycle waste, either organic or inorganic, presents another obstacle, considering that Mexican authorities have shut down waste dumps in Mexico City, for instance, Bordo Poniente in 2012, now, waste is accumulating in even larger amounts. (Godoy, 2012). A waste disposal system oriented to recycling would have to be implemented in the residential area in order to obtain the organic matter to feed the digesters.

Further, Mexico is transitioning to a composition with a predominance of organic matter: in the decade of the1950s, organic waste accounted for 65 to 70% of total volume, but by 2012, this figure has reduced to 52.4%. (SEMARNAT, 2015). In general, the prevalence of organic or inorganic trash is related to the population's economic situation: in lower-income countries, organic waste predominates, whereas in higher-income countries, waste is mostly inorganic, with a considerable number of manufactured items. (Acurio et al., 1997, as cited on SEMARNAT, 2015). This poses a challenge in coming years as organic matter is the main fuel for anaerobic digesters and its collection.

An important barrier, that may become a driver if the response is positive is social acceptance[3] in local communities, it can enable the development of a project or the impossibility of it to take place. There are a few factors that can influence the acceptance, for instance, a fair decision-making process, where everyone involved has the opportunity to participate in the project, furthermore, trust by local community in both, the information and intentions of stakeholders from outside and within the community, if there were to be involved. (Wüstengahen et al., 2007).

Laws, regulations, taxes, infrastructure requirements, can also appear as barriers for projects/initiatives, however, they can also become drivers; since institutions can be supportive because they promote interactions among a variety of stakeholders by assigning each one a certain role and setting expectations for how others will behave. (Hisschemoller, 2012).

Despite all the potential barriers mentioned above, important drivers can be seen, for instance, sustainable certificates. There are some certifications to which residences can apply, one example of these certifications is the LEED certification, in terms of savings, it makes sure that the households can transparently observe reduction on energy and water consumption. This can lead to lower utility bills. Even further, certified households consume 20 to 30 percent less energy than non-certified ones. Carrying out an initiative of these characteristics, *Casa de Campo* or any other residential area in which it takes place, could be benefitted by an important capital gain influenced by the current sustainability view that not only companies and organizations are having, but also, people, communities and societies, as this quote from the U.S. Green Building Council, 2021 illustrates: “Certified green homes are now selling quicker and for more money than comparable non-green homes”. Carrying out an initiative like the one presented in this research, opens up the possibility for the residence to apply for a certification, bringing all the benefits just mentioned.

[3] In Casa de Campo residential area as in many others in Mexico City, there is a group of people that form a committee which are inhabitants of the residential area, together with an administrator which is not an inhabitant of the residential area and acts as connection with public authorities as municipality or local government for regulation means or any other aspects which need to be taken care of for the residential area to operate.

Furthermore, transforming a waste management system, even in a small scale as it is the case of *Casa de Campo* residential area, poses a big challenge, which is why residents are identified as a key factor to have successful waste to energy technologies. Their involvement is crucial, but also having the right technology for the waste reduction and transformation is a very important factor for the success of solid waste management. Hence in the following sub-chapter, an introduction to the best available technologies to generate electricity that fits with the circular business models is presented.

2.5. Best Available Technologies (BAT) for waste to energy

One solution for reducing waste volumes and avoid filling landfills (or garbage deposits as it is the case in residential areas), causing pollution and health impacts is converting waste into energy. To achieve this, there are various techniques that allow MSW to be transformed into energy, like waste treatment plants, which are management facilities that mostly burn waste to produce electricity.

The main process that results in biogas is produced from biomass anaerobic biodegradation, lack of oxygen and anaerobic microorganism presence. Anaerobic digestion is a consequence of a series of metabolic interactions among several groups of microorganisms. (Souza, et al., 2013).

In order to install a system that converts waste to energy, like for example, a biogas plant, it is needed to estimate the biogas potential (energy content) in the waste stream, several methodologies allow to estimate that. For instance, Carranco, et al., 2020, presented a combination of two methodologies in their paper. The first of them uses urban solid waste composition to estimate biogas, while the second one converts biogas flow data into energy units. The resulting model is capable of estimating biogas from waste composition within any municipality in the study area, and it is also able to translate the potential biogas flow (in thousands of m3/days) into megawatts (MW). (Carranco, et al., 2020). This method is relevant given the complexity that low collection and separation levels in Mexico City pose, resulting in poor data gathering. (Carranco, et al., 2020).

To better understand what is mentioned above, it is important to mention what is biogas conformed of, so it can be evaluated if it is suitable for household use. “Biogas is composed mainly by carbon dioxide (30–50%) and methane (50–70%) and may contain several trace compounds depending on the organic source”. (Duarte, et al., 2020). “It also contains traces of hydrogen sulfide, nitrogen, hydrogen, carbon monoxide and oxygen, its concentration and volume are influenced by the source of organic matter. Residues containing bigger organic concentration generate biogas richer in methane”. (Souza, et al., 2013).

Following on methods to convert waste to energy, anaerobic digestion comes as an effective way to not only digest waste efficiently, but also good amounts of usable energy can be recovered without any serious carbon emissions. Anaerobic digestion (AD) processes can provide a significant solution when it comes to treatment of organic material, and concurrently can fulfill any other energy demands. Food waste is high in minerals and nutrients, making it an excellent feedstock for the anaerobic digestion process. This method is considered a renewable energy source because it creates methane-rich biogas, which is a strong alternative for replacing fossil fuels, and has the advantage of low emission generation. Additionally, the nutrient-rich remaining solid and liquid may be used as a fertilizer for the soil after digestion. This would increase soil fertility, requiring fewer fertilizers and insecticides for crop production. An anaerobic digestion plant not only helps mitigating pollution, but it also restores energy and agriculturally productive soil, decreasing greenhouse gas emissions. Methane is generated during the anaerobic digestion process, and this gas can be used as a carbon-neutral clean energy source. (Chowdhury, 2020).

Even though there are techniques to treat organic waste, precautions must and still be taken when discarding organics, given the threats that food waste possess by its quick decomposing and the risks of polluting air soil and water, creating serious concern on health, not to mention bad odor due to mercaptans emissions from the organic matter decomposition and the lixiviates from organic matter accumulation/transportation. (Ma et al., 2017 as cited on Chowdhury, 2020).

An anaerobic digestion process is built upon three main stages: first the Bio Wastages go into a Pre-Treatment stage, then the already treated waste goes in the Anaerobic Digestion plant where biogas is separated from the waste, finally, the waste goes to the post-treatment stage, becoming bio fertilizer. (Chowdhury, 2020). The anaerobic method reduces the volume and mass of the raw material and converts the waste into useful energy. (Zhang et al., 2014 as cited in Chowdhury, 2020).

The following table shows technologies whose implementation is feasible in the scale of *Casa de Campo* residential area:

Table 2: First Overview of Feasible Technologies. (ISAT, 2010)

Technology	**Characteristics**	**Advantages**	**Disadvantages**
Fixed Dome Biogas Plants	Digester with a fixed, non-movable gas holder, high methane emission and high gas storage.	Low initial costs and long useful lifespan.	Labor-intensive construction.
Low-Cost Polyethylene Tube Digester	Made from recyclable materials like tire tubes.	Already proven in Latin American countries like Mexico.	Constant maintenance.
Balloon Plants	Heat sealed rubber bag, gas storage in the upper part. Gas pressure can be increased.	Low-cost prefabrication, easy to build and transport	Short lifespan and difficulty removing residues during operation.
Earth-pit Plants	Dome-shaped digester with an immovable, rigid gasholder and a displacement pit.	Low cost of installation and high potential for self-help approaches.	Only suitable in impermeable soil.

Information and Advisory Service on Appropriate Technology (ISAT, 2010)

It is important to mention that besides the characteristics and potentials presented below, other factors like cost and residents opinion, as well as the regulatory Mexican framework that impedes or promotes some types of technologies, play an important role on which technology is more suitable for the residential area. Their selection has to be planned, even though most of these simplified technologies can work properly on a domestic scale, some have better performance in rural areas, or farms, because in these sites, manure is the main feeding product for the biodigester and have a more favorable solution for bio-methanation at a smaller scale, not to mention that each household is responsible for the system. (ISAT, 2010).

3. Methodology

This chapter presents how stepwise the research was carried out. Different aspects of the research design are here explained. Firstly, the research framework which is based on Designing a Research Project by Verschuren and Dooreward (2010), show the plan for the study target, followed by the theoretical framework, which presents the theoretical base for the research, then the research strategy is elaborated per research sub-question. The data analysis is presented as well. This is explained to illustrate what was the data needed for this research as how it was collected. Finally, the ethics statement, with the ethical principles of the research.

3.1. Research Framework

Based on the book of Verschuren and Dooreward (2010), a research framework provides a step by step follow up for achieving the study target, seven steps conform the Research Framework, and these are shown below:

Research project´s objective:

Determine if self-organization can influence the transformation of waste management in residential areas in order to plan the circular model that best fits Mexico City´s conditions to reduce household´s waste related impacts and utilizing waste as the source of household´s generation of electricity.

Research object:

The research object in this thesis is Waste Management Treatment in residential areas in Mexico City, specifically *Casa de Campo* residential area.

Research perspective:

The research observes waste management system in Mexico City and how it reflects in residential areas, it also analyses how self-organization can create a cohesion that transforms waste management systems in residential areas and the possibility of utilizing organic waste to supply electricity to the residential areas by a circular approach.

Sources of the research perspective:

Literature review will be used to develop the research, the following theory will be used in the research:

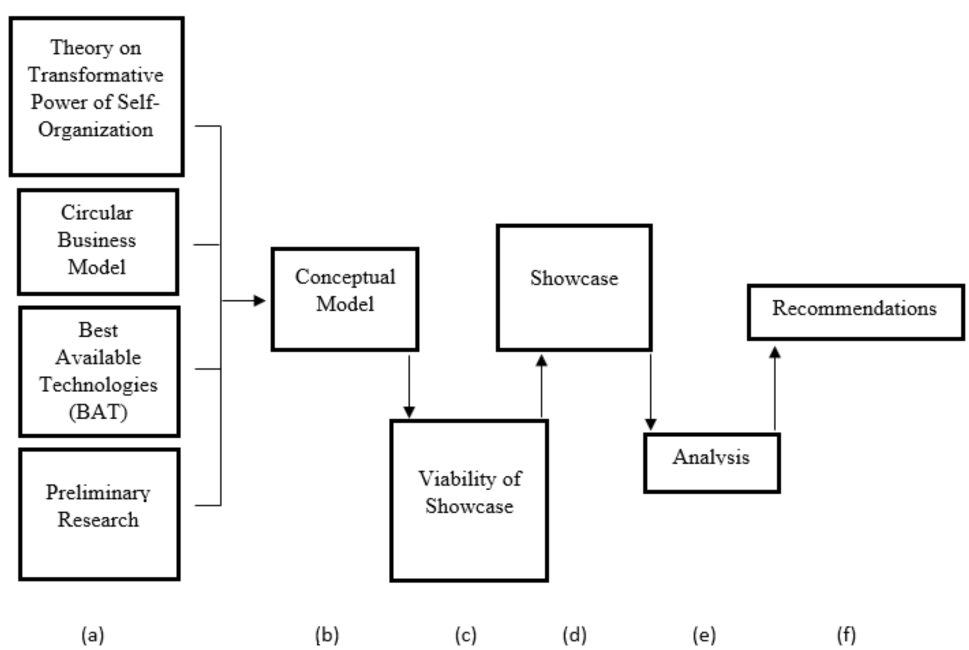
Table 3: Sources of the Research Perspective

Key Concepts	**Theories and Documentation**
Self-Organization Social-institutional energy projects Waste to Energy	The Transformative Power of Self Organization for understanding Local Energy Initiatives

Research Framework Scheme:

The following scheme describes the research framework:

Figure 1: Research Framework Scheme



Arguments to formulate the research framework:

(a) Analysis of the literature of each aspect as well as the research already presented in this proposal.
(b) Result in a Conceptual Model.
(c) Present the feasibility of the show case to be presented.
(d) Show case research.
(e) Analysis of showcase for further recommendations.
(f) Recommendations for applying a circular model in residential areas.

Review the model for if changes are required: there are no indications that the model requires any changes.

3.2. Research Strategy

The research focuses on the implementation of a local energy initiative in Mexico City´s residential scale to provide a solution for high waste volumes and electricity supply, with self-organization as the main driver. The main approach is a mix-research approach, i.e., combination of desk research, survey and semi-structured interviews.

The research unit is the residential areas in Mexico City, specifically *Casa de Campo*, will serve as a showcase, further explained in 3.4. Administrative figures of the mentioned residential area, population of the residential area, governmental (legal, requirements, figures) attached to the residential area were addressed with interviews and surveys for the development of the section.

The data analysis was carried out with both qualitative (desk research and interviews with semi-structured questionnaires) and quantitative methods (survey). For data like Drivers and Barriers of implementation, the information gathered provided a qualitative result, as well as for the Best Technologies available, showing what are the main obstacles for implementation and its motivations; for best technologies, the data collected presents with techniques that best suit the research object´s conditions.

The quantitative method enabled the research to collect data on technology, financial and spatial acceptance from inhabitants of the study area.

3.3. Data Collection and Analysis

The research conducted two interviews (shown in Appendix B and C) and one survey (shown in Appendix A). The interviews were carried out with the administrative figure of *Casa de Campo* and with one of the maintenance workers of the residence. The administrative person provided information mostly about regulations, both internal and external to the residence, as well as barriers for the technology´s installation. As for the interview with the maintenance worker, it provided information about waste generation and separation culture and behavior of the residence´s inhabitants.

The survey was carried out to collect data about the level of involvement of inhabitants and the characteristics they considered more important to implement the initiative promoted during the research.

The following table shows the data and information required for the research as well as the methods employed to collect and analyze data:

Research Methodology

Table 4: Data Collection and Analysis

Research Question	**Data for Answering the Question**	**Sources of Data**	**Data Collection**	**Data Analysis**
What are the main characteristics of an initiative that successfully reduces waste generation in Mexico City´s residential areas by generating energy through a circular model?	BAT, Business Model, Social participation.	**Secondary Data:** Literature **Primary Data:** Household´s inhabitants, administrative and local government.	For Secondary Data, content review. For Primary Data, online interviews and surveys.	For Secondary Data, qualitative analysis. For Primary Data, qualitative analysis method.
Research Sub-Questions	**Data for Answering the Question**	**Sources of Data**	**Data Collection**	**Data Analysis**
What are the main drivers and barriers of a circular model for a waste reduction initiative?	Population, waste amounts and type, weather.	**Secondary Data:** Literature and documents	Review of content in literature, documents and waste generation research.	Qualitative and quantitative analysis method.

What technology might be suitable for the residence serving as show case in this research?	Financial information, benefits for inhabitants.	**Secondary Data:** Literature **Primary Data:** Household´s inhabitants	For Secondary Data, content review. For Primary Data, online interviews, survey and waste generation research.	For Secondary Data, qualitative method. For Primary Data quantitative analysis method.
What are the main characteristics of a circular business model for stakeholders?	Government involvedness, current electricity supplier(s), financial matters.	**Secondary Data:** Literature **Primary Data:** Residential area administrative and household´s inhabitants.	For Primary Data, online interviews and waste generation research. For Secondary Data, content review.	For Primary Data, qualitative and quantitative method. For Secondary Data, qualitative method of analysis.
How can self-organization be a driver to implement Local Energy Initiatives at a residential scale?	Feasibility of social cohesion in study area.	**Secondary Data:** Literature **Primiary Data:** Household´s inhabitants	For Secondary Data, content review. For Primary Data, online interviews and surveys.	For Secondary Data, qualitative method for analysis. For Primary Data, qualitative method.
	Incentives for WM transformation	**Primary Data:** Residential area administrative and household´s inhabitants.	Online interviews.	Qualitative Method of analysis.

Finally, a waste generation research, further explained in 4.1., was conducted in the residence with the purpose of collecting data that enabled the research to select a better suitable technolgy, as well as calculate the potential energy generation through waste. Not every household participated in the research, so the data collected and analyzed provided but an approximate number of real waste volumes and energy generation. However, the data collected assisted on answering the research questions.

3.4. Showcase Selection

The time frame for the thesis development was limited and the research in a megacity like Mexico City would have required a large study area to collect the data needed, not only because of the geographical extension but because various socio-economical levels of residences can be found there, hence, waste generation in terms of volumes and types can vary as well. During this research, the researcher was not located in Mexico City, which presented another difficulty to fulfill a successful study in the city, therefore, the research was focused on one residential area, called *Casa de Campo*, in Mexico City, in which an Organic Waste Generation research was carried out to collect data, this research is further explained in 4.1. Another factor to select *Casa de Campo* as showcase was the existing familiarity of the researcher with the residence, which opened access to informants and information.

Generation of waste residuals is strongly linked to the process of urbanization, in general, it is recognized that this is accompanied by an increase in the population's purchasing power, which leads to improved living standards and higher levels of consumption of goods and services, resulting in higher volumes of waste. (SEMARNAT, 2015). This residential area covers the characteristics needed to carry out the research, being these, having a group generating organic waste in a regular basis and different sources and types of organic waste, part of the urbanization process, just to mention a few.

To have a better overview of *Casa de Campo*, a description is presented as follows: the number of houses in this residential area is 90 of approximately 190 square metre each including a small yard, four people in average live in each house. The average selling price of each house is of $15 million [4]pesos (626,507 €). Furthermore, the research will focus on organic solid waste.

3.5. Ethics Statement

During the data collection, every interview was carried out including voluntariness of participation and with previous knowledge from the interviewee of the nature and purpose of the interview, as well as the aim of the study. The interviewee had the right to refuse to

[4] Exchange rates: 23,94 MXN for every 1 €. 8/4/2021. Google exchange rates, euros a pesos mexicanos - Google zoeken

engage in the study and withdraw from it at any moment, with no repercussions and without giving any argument, ensuring that the information provider has control about their own involvement, consequently, a written form was handed to the interviewee before the interview. If applicable, recordings and images publishing were previously authorized.

If the interviewee requested confidentiality, anonymity was preserved, namely, information was not to be shared with anyone. The information is kept in a computer devise, and safely protected with secure software.

Finally, the questions asked during the interviews did not jeopardize the interviewee, meaning that the interviewee was not put in the position of having problems for any answers provided, therefore, interviewee´s integrity was guarded at all times during the interview.

4. Findings and Discussion

This section follows the same structure than Chapter 2, to present the research findings and provide answers to the main research questions. In this chapter data and information analyzed have diverse sources: additional literature and information provided from waste collectors of the residential area, interview with administrative personnel and surveys involving *Casa de Campo* inhabitants. As priory mentioned, to measure the organic matter generation was crucial to study the feasibility of biodigestion *in situ*, hence this chapter starts with the quantitative study of organic matter generation in Casa de Campo in order to identify the technology that might be suitable for the residence in terms of operational capacity.

4.1. Organic Waste Generation Research in *Casa de Campo*

In order to select the technology that might suit the residence´s characteristics and present a complete Circular Business Model, it was needed to have data about the amounts of organic waste generated on a daily and weekly basis inside the residence. To collect this data, a research within the residence was carried out, based on the Mexican Regulation NMX-AA-15-1985, which is about solid waste data collection sample.

Inhabitants of *Casa de Campo* were reached out and asked if they were willing to participate on this research, after explaining what the participation was about, a group of people representing each, household agreed on providing data of their organic waste generation. They were asked to register the weight of their organic waste every day during a week, and in order to do this they were provided with a chart in which they could put a mark on the weigh that corresponded to that particular day.

The research was successfully completed after one full week (7 days), in which the 8 participant households provided their organic waste bags weight each day of the week, with which an average weight was calculated for the entire week, approximately 900kg of organic waste are generated in a seven-day week per residential unit This data enabled to give an overview of the energy potentials that organic waste could bring to the residence, namely financial benefits, clean energy generation and more specifically, to calculate the volume of biogas the biodigester could generate from waste. Biogas generation was then converted[5] to kWh to show the electricity supply households could have access to from this initiative, and all the financial benefits that it could potentially bring.

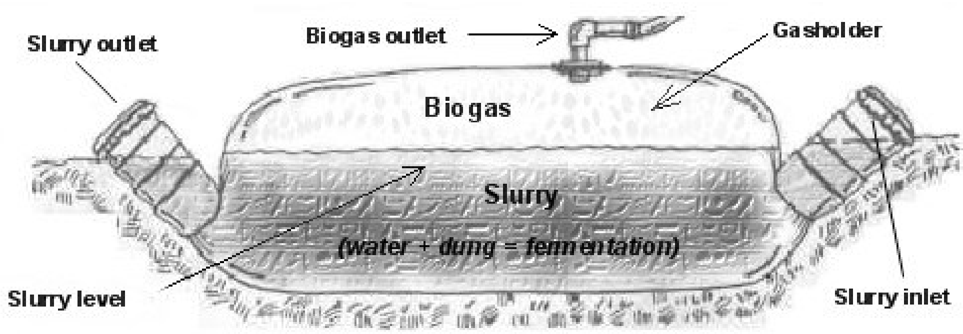
The research, offered a clearer view of the realities in the residence regarding the resources (organic waste), facilitating the selection of the technology, which is further explained in the following subchapter.

4.2. Suitable Technology for transforming organic waste to electricity

As mentioned in chapter 2.5, there are several techniques that allow the transformation of organic waste to energy, in this chapter, the research provides with one of these techniques that might be suitable for the characteristics of *Casa de Campo*. Starting by mentioning that the technique selected is a Low-Cost Polyethylene Tube Digester, given its characteristics of reduced costs and easy installation process. An important factor for considering this technique as the most suitable, is that it is already being applied in Latin American countries, like Bolivia, Perú, Ecuador, Colombia and Mexico (ISAT, 2010). This can be a guarantee in the performance of the digester, since it has already been proven in similar climate conditions, like weather temperatures or altitude. It is built with a tubular polyethylene film which is bend at each end around a 15 cm PVC drainpipe and hold together using a rubber strap obtained from recycled tires, this gives as a result a hermetic isolated tank system. Figure 2. shows and explains how this system works. (ISAT, 2010).

[5] 1 cubic metres of biogas translates to 10.55 kWh. With data from Gas Consumption Calculator – Conversion of m3, kWh, MWh. And considering that methane content of biogas ranges from 45% to 75% by volume. Information from IEA,2021.

Figure 2: Scheme of Low-cost Polyethylene Tube Digester. (ISAT, 2010).



One of the 15 cm PVC drainpipes serves as the slurry's inlet, while the other serves as the slurry's outlet. Finally, in the tube digester, a hydraulic level is formed, allowing as much added prime matter (a mixture of dung and water) as fertilizer to exit through the outlet. The capacity of the gasholder is of about one fourth of the total capacity of the system, to solve the issue of low gas flow rates, polyethylene reservoirs (figure 3) may need to be installed, to store the additional gas generation. (ISAT, 2010).

Figure 3: Gas Storage Reservoir. (ISAT, 2010).

However, a pit must be built, where the bag will be located as shown in figure 1. *Casa de Campo* has a space determined with a small warehouse to place the waste once it is collected from each house in organic and inorganic bags. This area offers the space to build this pit and locate the biodigester, which poses a huge advantage given its closeness to the source of feeding material. The warehouse offers protection to the biodigester from animals and weather with a roof and doors which isolate the system from threats.

Furthermore, three main factors are to be considered for the location of the biodigester, one of which has been already mentioned:

- Closeness to waste disposal.
- Flooding areas should be avoided.
- The pit, if possible, should be located on the lower side of the source of feeding material for an easier flow into the biodigester.

Once the biodigester is installed and being constantly fed, for instance, with 20 kg of waste a day, it has the potential of producing, after one to two months, around 4 to 5 hours of biogas every day, which can be used for cooking or electricity applications. (energypedia.org, 2014). It is important to mention that the waste must be mixed with water, approximately a ratio of 60% organic waste feed and 40% water, this ratio has been tested in similar temperature conditions as Mexico City, resulting in the most effective for biogas generation. (Basumatary et al., 2021). However, the biogas generation will be adjusted to the actual waste generation in *Casa de Campo.*

After the biodigester has been fed, it is important to consider the slurry. An interesting solution for it is using it as fertilizers. In *Casa de Campo* it can be used for both house yards and common areas. After the anaerobic digestion process, the content of nutrients is not very much affected so in this case, yards can still benefit from the slurry´s nutrients. However, not all the slurry can be used as fertilizer, either because it is not needed at the moment or the generation of it is more than that of what is needed, in this case, storage is necessary. There are several options for storage, but the ones that appear as more suitable for the residence´s conditions are vessels or tanks. To store the slurry is best to separate it in liquid and solid parts. (Bonten et al., 2014).

To assess the technology´s feasibility for implementation, a description of costs and system operation is needed, as well as financial information of investment, and safety issues covered by insurance, which is why a Circular Business Model is needed as part of the initiative.

Discussion

A Low-Cost Polyethylene Tube Digester might be the suitable technology for the characteristics of the residence, considering its easy construction, application, and low costs. The technology was selected after comparing it with other similar and potential technologies, weather conditions, economic investment, and easy installation and operation where the main aspects that led to choose the technology. The following aspect researched, showed through a survey carried out in the residence, that the financial budget was enough to consider the installation of the technology, although not enough for covering all the aspects surrounding the initiative.

4.3. Circular Business Model

As mentioned, the CBM intents to provide financial information, as well as legal policies and regulations to be as most transparent as possible with all the stakeholders involved. This subsection presents the main characteristics of the CBM.

Costs

In the case of the technology, a Low-Cost Polyethylene Tube Digester is built using a series of materials, which can be obtained after discarded giving them a second use in its lifespan, these materials are tires and PVC tubes. The material can be purchased in a local hardware store. Table 5. shows a complete list of materials and approximate costs due to price variations between different stores. The cost of building this type of biodigester is of about $5,000 pesos (208,85 €) which can be less if more materials are obtained from recycling residuals. (Ortega, 2009). The costs of workforce are not included in the table, but these costs can be of approximately $5,000 MXN monthly, making the total cost of building the digester amount to $10,000 MXN (417,71 €).

Table 5: Costs and materials (Ortega, 2009)

Material and Activities	Quantity	Unit	Unit Cost MXN	Cost MXN	Cost EUR
Polyethylene bag	1	bag	$ 2,880	$ 2,880	120,30 €
PVC tube 30.48 cm	3	cm	$ 5	$ 15	0,62 €
Buckets	8	unit	$ 50	$ 400	16,70 €
38.1 cm transparent plastic hose	5	cm	$ 33	$ 165	6,89 €
Male adapter 1"	1	unit	$ 9	$ 9	0,37 €
Female adapter 1"	1	unit	$ 9	$ 9	0,37 €
Elbows 1"	2	unit	$ 10	$ 20	0,83 €
PVC cap 1"	1	unit	$ 24	$ 24	1,00 €
Tee 1"	1	unit	$ 14	$ 14	0,58 €
Bicycle tube	4	unit	$ 50	$ 200	8,35 €
PVC glue	1	unit	$ 50	$ 50	2,08 €
Rubber seals of used tires	2	unit	$ 25	$ 50	2,08 €
Hacksaw blade	1	unit	$ 30	$ 30	1,25 €
Empty fertilizer bag	4	unit	$ 10	$ 40	1,67 €
PVC lenths	5	610 cm	$ 110	$ 550	22,97 €
Reducers 1 - 1/2"	2	unit	$ 17	$ 34	1,42 €
Ball valves 1/2"	2	unit	$ 65	$ 130	5,43 €
Elbows 1"	4	unit	$ 10	$ 40	1,67 €
Tees 1"	1	unit	$ 13	$ 13	0,54 €

Technology Operation

It must be considered that the digester has to be operated on a daily basis. The operation means, constant feeding and maintenance, as mentioned by Ortega, 2009, “if properly maintained, digesters can last up to 10 years”. The digester will be located on a secluded space, providing isolation from the sun, rain and animals, as well as being in a secure area for kids that live in the residential area. The estimated time for the biodigester to begin producing biogas is between 35 to 60 days; this highlights the importance of a constant and proper feeding which can be adjusted to the amounts of organic waste generated, given its advantage of “combination possible” sizing (Ortega, 2009), a very useful feature considering that organic waste generated in *Casa de Campo* varies from that of other residences. Thus, for the purpose of providing the kWh generation numbers, the research takes a household average digester size, which is of about 8 to 9 cubic metre in capacity. (GIZ project experience from energypedia.org, 2014).

With 20 to 25 litre of waste, the digester can produce an average of 1 cubic metre, or 1000 litre of biogas in a day. (Thomas H. Culha…, 2014). As mentioned above, 1 cubic metre of biogas translates to 10.55 kWh.

Financial benefits and Investment

Table 6. illustrates the financial benefits of installing a biodigester of these characteristics according to the monthly electricity consumption per household and current electricity fee, calculated based on CFE rates and shown in Appendix D.

Table 6: Financial Benefits of the Technology with a household average digester size.

	Monthly Electricty fee per household	Monthly Electricicty consumption per household	Avg. Biodigester biogas capacity generation	Number of households in *Casa de Campo*	Biodigester biogas capacity generation per household	Monthly benefit per household
Unit	$ MXN	kWh	kWh	Houses	kWh	$ MXN
Quantity	467,87	250	896,75	90	9,96	18,65

*The numbers may change depending on the amounts of waste, the more waste there is to feed the digester, the greater the savings, and variations may happen from month to month.

The monthly electricity fee per household was calculated using the average consumption per household of 250 kWh every month and CFE rates, in the following way:

75 kWh * $0.861 MXN + 65 kWh * $1.043 MXN + 110 kWh * $3.050 MXN = $ 467.87 MXN

Using the same data of electricity consumption rates and CFE rates, the information in Table 7. is provided using the data gathered from the research conducted in *Casa de Campo*, which as mentioned in 4.1. showed that in average, 900 kg of organic waste are generated in a seven-day week, 36 cubic metres or 36,000 litres of biogas weekly (5,143 every day). With these amounts of waste, the biodigester could produce 380 kWh every week and 54 kWh[6] every day assuming constant temperatures.

Table 7: Financial Benefits of the Technology according to research data

	Monthly Electricty fee per household	Monthly Electricicty consumption per household	Biodigester weekly biogas generation (according to data)	Biodigester monthly biogas generation (according to data)	Number of households in *Casa de Campo*	Biodigester biogas capacity generation per household	Monthly benefit per household
Unit	$ MXN	kWh	kWh	kWh	Houses	kWh	$ MXN
Quantity	467,87	250	380	11400	90	126,67	237,05

As we can see in the table, the biodigester´s characteristic of "combination possible sizing" makes it possible to be built with the capacity to produce 380 kWh every week, calculated using the data collected from the organic waste generation per household in *Casa de Campo*; this translates to a generation of 11,400 kWh each month, where every household is supplied

[6] This compares to an average monthly electricity consumption per household of 250 kWh, 20.83 kWh daily.

with 126,67 kWh every month, saving $237,05 MXN from the monthly electricity bill. The savings for the whole residential area would be of $21,334 MXN per month, so the total estimated initial investment of $10,000 MXN will be covered in the first month, from a financial point of view. Hence, the first month means, from the moment the biodigester starts generating biogas, as mentioned previously, this type of biodigesters usually take thirty to sixty days to begin producing biogas regularly. (Ortega, 2009). So, inhabitants should consider up to two months to cover the initial investment and the savings in the electricity bill.

The financial benefits can only be seen if, as already mentioned, the digester is operated every day, which requires workers dedicated to this task. *Casa de Campo* currently employs two people, whose job is delivery[7] (newspaper, and postal service deliveries) and maintenance, as well as picking up waste from every house and taking it to the waste disposal before being collected by the local authorities. Both can be trained to operate the biodigester and separate the slurry for future use as fertilizer, as confirmed by the residence´s administrator during an interview (Appendix B), Ms. Garduño, "… as long as the digester´s operation allows their other activities to be fulfilled, they could participate in the initiative as operators". And confirmed by one of the maintenance employees, Mr. Martínez, during an interview (Appendix C), mentioning that he would be interested in receiving training for operating the biodigester. However, one of his comments was about the salary or an economic reward, which was considered as part of the initiative as an increase in their salary or an economic remuneration as he mentioned, for which residence inhabitants were asked in a survey (Appendix A) about their willingness to increase the current monthly maintenance fee, among other important data which will be useful for answering the Drivers and Barriers of the project. The survey was answered by 33 percent of the total inhabitants, covering a representative sample, providing the following data:

[7] Casa de Campo is a private residential area where only inhabitants have access to, this is controlled by hired private security 24 hours a day. Security needs authorization from inhabitants to allow non-inhabitant to enter the residence. Therefore, deliveries are left in the security booth, to be handed to every house by the two people of maintenance.

- 63.33% of the answers about the increase in a maintenance fee represent those inhabitants that are willing to increase[8] the fee from $100 MXN to $300 MXN.
- The rest of the answers are divided in 20% of those who are willing to increase their monthly payments from $301 MXN to $600 MXN, 10% who are willing to increase the fee from $601 MXN to $ 1000 MXN, and the remaining percentage of 6.67% of those who will be willing to increase the fee from $1,001 MXN to $1,500 MXN.
- According to this data, all inhabitants will be willing to pay an extra $100 MXN to $300 MXN which provides the initiative with a budget of $27,000 MXN.
- The budget would be sufficient to cover the initial investment calculated on $10,000 MXN, leaving $17,000 MXN which could be employed for the salary rise or economic remuneration for the maintenance employees of *Casa de Campo*.

The circular business model has now covered the financial benefits of the technology, costs of building the digester, as well as investment and operation. The following part covers the safety issues that have to be addressed by hiring an insurance.

Insurance

Insurance is an important issue to cover as mentioned in chapter 2. In this regard, AXA insurance company offers a product called Liability Insurance for the Industry and Commerce Sectors. AXA describes responsibilities covered as follows:

[8] In the case of the increase in the fee, it could pose a threat to household's economies, but Casa de Campo is a middle class residence, which means that the average income per household is of $64,000.00 MXN, or 2717,31 €, (23,55 MXN for every 1 €, 15/7/2021, Google exchange rates, euros a pesos mexicanos - Google zoeken), this according to a research from the journalist Viri Ríos published in the New York Times on July 6th 2020. Considering this average income, the impact for the mentioned increase wouldn´t jeopardize household´s economies.

Environmental Pollution – damages to third parties, in their property or their persons, caused by harmful variations of water, atmosphere, floors, subfloors, or by noise, which may occur within the insured properties, in a sudden, unforeseen, and accidental way. (AXA Seguros, 2020).

Assumed Civil Liability – External responsibilities assumed by the insured, by agreement or contract, for repair or indemnify damages to third parties in their goods or people. (AXA Seguros, 2020).

Employer Negligence – Responsibilities derived from the Federal Labor Law, the Social Security Law or other complementary provisions of laws mentioned, only in relation to accidents at work. (AXA Seguros, 2020). Particularly important for the operators of the digester, role executed by *Casa de Campo* maintenance employees.

Union, Mixture and/or Product Transformation – Responsibilities for damage to property products as a result of a union and/or mix of insured products with other products, or as a result of a transformation of the insured products. (AXA Seguros, 2020). Considering the installation of the biodigester facility in an existing property.

Demolition – Responsibilities for demolition work and demolition of buildings. (AXA Seguros, 2020). The installation of the digester will require a modification/adaptation in the determined area for it.

Infrastructure – Responsibilities for damages caused during foundation works, construction of galleries, tunnels, bridges, dikes, retaining walls, towers, and cranes. (AXA Seguros, 2020). This one is linked and compliments the previous coverage.

Underground Facilities – Underground liabilities derived from damages caused to pipes, cables, canals, or other underground facilities. (AXA Seguros, 2020). This would depend on the building planification, namely, if the biogas produced by the digester will be supplied through underground or on ground pipelines.

Machinery – Responsibilities derived from providing third-party with machinery for work and supply electrical or pneumatic force. (AXA Seguros, 2020). Of high importance for the maintenance employees, who would be directly operating the digester, referred here as the machinery.

Slurry leakage is a hazard that must be addressed by the insurance hired, this due to the gases it contains, for instance, methane or hydrogen sulfide, which exposure to them can bring along health issues. (HSE, 2015).

It´s important to mention that this insurance is mostly for companies, or big facilities, which is why the cost is high, however, these, or similar aspects must be considered when hiring an insurance. In the following subchapter, the high cost will be addressed as a barrier for the initiative.

Discussion

The circular business model considered the economic benefits of applying the initiative, in this regard, the findings were positive, given that a significant potential reduction in the monthly electricity bill could be achieved. This was possible through the waste generation research carried out, which provided data that showed that the organic waste could potentially generate 126.67 kWh for each household, meaning a reduction in the electricity fees currently paid to almost half as mentioned above.

Insurance was also considered as part of the circular business model, presenting the main characteristics it should cover for this type of initiative, however, the costs for hiring one that covers all of them is a barrier to overcome. In terms of material costs for building the technology, these can be purchased in local stores at very low costs, achievable for the initiative´s budget.

The CBM considered the operation of the technology, task that can be fulfilled by the current residence´s maintenance workers. The salary or payment in exchange for performing this job is an issue that needs to be further discussed with the residence´s committee. This and other barriers are covered in the following subsection.

4.4. Drivers and Barriers of the initiative

During the interview with Ms. Garduño, she revealed that there are no requirements from the local government or from the residence´s administration for projects of these characteristics, in fact, she mentioned that it was considered to install solar panels for the residence´s common areas use, and that the main obstacle were not requirements or regulations, but a reduced budget.

Furthermore, the survey conducted obtaining 30 replies, identified the importance inhabitants give to certain aspects that the initiative could bring along if implemented, and that make it attractive for them, thus, they have the potential to impulse the initiative:

- A better management and handling of organic residuals at a local level with 53.33%
- A reduction in the electricity rates with 50%
- Transportation service reduction costs (garbage truck needed for picking up the residuals and transporting it to treatment plants) with 23.33%
- Providing education about environmental care and awareness was considered an important driver for one of the participants, as well as a good use for waste and residuals which would enable the residential area to become self-sustainable.

During the research, other actions were identified as drivers, according to the high percentage of replies in the survey, for the applicability of an initiative with these characteristics. The scalability of the project, so it is adopted as model for similar initiatives in other residential areas was mentioned by 66.67% of inhabitants, followed by a confirmed collective action inside the residential area with a 33.33%. The latter is particularly important in the research given the theoretical framework employed; this confirms that inhabitants of *Casa de Campo* highlight the importance of working together in order to make these projects/initiatives work successfully. Socio-institutional coalitions were also identified as important drivers. Even though there is an important interest from inhabitants to not only support but participate in the project, "approximately 50% or forty-five to fifty households do a separation of waste, the ones that do not engage in separation seem as they have no interest in modifying these actions, given that they have been advised and asked to do a waste separation without successful responses", as mentioned in the interview (Appendix C) with the maintenance worker Mr. Martínez. Furthermore, the interview revealed that there are no sanctions of any kind for not separating the waste, so the administration of the residential area can only ask and wait for these households to separate their waste. The poor engagement on waste separation of almost half the residential area may be an important obstacle for the full potential of energy generation by the digester. The data shown in 4.3. considers every household´s involvement in the maintenance fee increase and waste separation, which is why is of high importance to have a full participation.

Mr. Martínez also mentioned another potential barrier; the workers from the waste truck that picks up the garbage from the waste deposit in *Casa de Campo*, select and sell some of the waste. The waste selected and sold is inorganic waste but an initiative that considers utilizing residuals which mean an extra income for the truck workers, could be jeopardized if not handled properly. Which is why, truck workers must be asked for a meeting in which they are explained not only the benefits of the technology, but also that inorganic residuals will still be available for them to select and sell, even in a cleaner manner, considering that they might still collect mixed waste (organic and inorganic).

During the interview carried out with Ms. Garduño, she mentioned that one possible barrier could be the supply of biogas from the biodigester to every house, considering that the residence has 90 households, this could probably require an infrastructure job for laying pipelines. At this point, it is relevant to mention that in *Casa de Campo* is not allowed to install exposes pipelines or wires. However, this doesn´t mean that the initiative is not feasible; the biodigester could be considered for supplying common areas, it would be located in the main common area of the residence, making the supply much more accessible. In terms of regulations, Ms. Garduño was asked about local government´s involvement, and she mentioned that even though there are no sanctions, economic or any kind, there have been petitions for waste separation, in which residence inhabitants are asked to separate their waste in four different categories and each category is to be picked up on a specific day of the week. The problem comes when the garbage truck, being aware of the situation do not follow the rules, picking up waste of any category any day. This is one of the main challenges the residence´s administration is facing, because inhabitants find it easy to either not separate their waste or not comply to separation rules, which poses the possibility of the residence providing internal education campaigns.

All regulations come as soft law[9], both externally and internally to the residence. This can be considered a barrier for the initiative, as there are no enforceable regulations to motivate waste separation, at the moment the initiative relies only on inhabitant's desire for separating their waste, and as mentioned in this subchapter, only half the residence is currently engaging on separation.

As mentioned in 4.2., the biodigester not only needs organic waste but water to create the mix that feeds the system. This of course, poses the situation of water consumption, which will add to the current residence´s demand, resulting in higher costs on the water bill of the residence.

Furthermore, and as mentioned in the previous subchapter, the cost of hiring the insurance presented would become a barrier, not only the minimum coverage amount is of $100,000 MXN (4.177,10 €), but it is suggested by the insurance company, that the minimum insured sums hired are of $4,000,000 MXN (167.084,37 €).

With an optimistic budget of $27,000 MXN, in which $10,000 MXN would go for the initial costs of building and installation of the digester, leaving $17,000 MXN, and as also mentioned, this would go for the salary of the maintenance employees. Even if the whole amount is not used for the salary, it wouldn´t leave enough to cover the costs of insurance. The possibility of asking the inhabitants for a higher increase in the maintenance fee does not present itself as feasible, considering the answers that the survey provided (most inhabitants agreed on no more than $300 MXN). The option then, is to look for a different product more suitable for the scale of this initiative.

Finally, the biodigester will produce biogas but for it to be utilized to power households, it first needs to be converted into electricity, this is another barrier for the initiative. For this process it is necessary to have a combustion engine, which converts the biogas to mechanical energy, powering an electric generator to produce electricity, so the installation of another facility for the engine will be necessary. However, this is not the biggest obstacle within the conversion of the biogas, but that the engine requires the production of clean biogas which

[9] According to the Organization for Economic Co-operation and Development, soft law is "Co-operation based on instruments that are not legally binding, or whose binding force is somewhat "weaker" than that of traditional law..."

is not guaranteed by a Low-Cost Polyethylene Tube Digester. (Electricity Generation from Biogas, 2016).

Discussion

A series of barriers were found that first would have to be addressed to plan a strategy that enables the initiative to take place. The rise in the salary or an economic reward for the maintenance employees that would be trained to operate the digester, needs to be further discussed with the administration committee and the inhabitants of *Casa de Campo*. The budget presented in the research, allows the possibility of hiring them for this initiative, but the exact number would need to be discussed and approved. Following on the estimated budget presented, it is not enough to cover all the requirements of an initiative with these characteristics, even further, the need of a combustion engine that converts the biogas to electricity adds another challenge in terms of budget, and spatial planning for installation.

The water demand to create the mix for the digester, becomes another barrier for the initiative, as more water demand means a rise in the water bill of the residence, which adds another hurdle for the budget. In terms of installation, the biogas supply poses another big challenge. The residence does not allow exposed wires or pipelines, this means that an important infrastructure work must be planned for installing a supply system, which will directly impact on the budget. The conversion of the biogas to electricity is another big challenge in terms of financial limits, biogas cleanliness production, as well as spatial planning for the combustion engine. Furthermore, the amounts of potential organic waste to be collected are limited given that an increasing number of houses in *Casa de Campo* have an organic residual processor[10].

According to community´s involvement, although the research found that there is high interest in being involved in the initiative from almost half the inhabitants of *Casa de Campo*, there are certain factors in local participation that can become a barrier of implementation, for instance, the lack of interest shown by the other half of the inhabitants, with a poor waste

[10] In an organic residual processor, food waste is disposed and shredded, to end up in wastewater treatment facilities.

separation, which poses a situation in which asking for an increase in the maintenance fee may not be feasible, as these households will most likely, not be willing to do so.

In terms of regulations, both external and internal, the researcher found that this do not appear as barriers of implementation, resulting in financial issues, as well as engaging in more local involvement as the main factors that could hinder the initiative to take place.

The main driver found was the involvement of inhabitants, as revealed by the survey carried out, a large number of responses related to their interest in being part of the initiative. It is important to mention that this is considering only the inhabitants that answered the survey, for the other inhabitants that provided no answer, it is assumed that they do not have the same interest in being involved. This is further discussed in 4.5.

Overall, the research found that it is possible to carry out an initiative of these characteristics, although it requires a higher local involvement and an increase in the budget, these two factors appear as the major barriers of implementation. Inhabitants not only have to express an interest but also be convinced, without their full involvement there would be an impediment to access organic waste residuals, given that this happens through a waste separation made by inhabitants themselves. In addition, even without enforceable regulations, if inhabitants are involved, they will engage in activities that enable the initiative to be successful, namely, economic and involvement support.

4.5. Self-Organization as a driver for implementing Local Energy Initiatives at a residential scale

On May 19th the first contact was made with *Casa de Campo* inhabitants, with the purpose of explaining the research development and inviting them to be involved on it on a data collection activity (explained in 4.1.). The answer was excellent in terms of interest and involvement, with added value because they not only were willing to participate but also provided with articles and useful information about the research´s topic. In fact, once the research activity was finished, some of the inhabitants that participated on it, when sending their data, asked about the possibilities of the research to become a reality, and again, openly expressing their willingness to be involved in further activities. Given that the research is based on Self-Organization in order to carry out Local Energy Initiatives, the answer received enables the possibility of hypothetically implementing a successful project.

The survey conducted, enabled the researcher to get a deeper insight on how far the involvement of the local community goes. The results showed that 100 percent of inhabitants (which represents 30 percent of the total residence´s population) that answered the survey, agree on an increase in the maintenance fee to enable the possibility of installing a biodigester, as mentioned in 4.3., which provides a clear answer of the interest of people of not only be involved, but also on supporting an initiative of these characteristics.

In addition to what is described in the Circular Business Model, inhabitants were asked about what they consider as benefits for investing in an initiative of these characteristics, the most popular answer was an environmental benefit (83.33% of participants selected this option), so according to this, people are aware of the environmental needs and of course the active participation its care requires; they are attracted to initiatives that promote an environmental approach. It is important to mention that for this question in the survey, participants could select more than one option (see appendix A), so inhabitants considered other options as benefits as well, but an environmental benefit was considered most important for most inhabitants.

Discussion

During the research an important number of barriers for the initiative were found, namely, financial, electricity supply, and even low participation of inhabitants. The key factor to address these obstacles is self-organization; through it, efforts for increasing the budget can be achieved, which could solve issues like electricity supply, energy transformation engine, or even salaries. Finally, inhabitants themselves can encourage others, who are not convinced to get involved in the initiative.

Even though only a section of the residence´s inhabitants showed interest and were engaged in waste separation activities, it is enough to begin conversations about an initiative, which will lead to strategic planning, ideas on how to access a larger budget, and strategies to address all obstacles and barriers.

5. Conclusion and Recommendations

Recalling on the main research question: What are the main characteristics of an initiative that successfully reduces waste generation in Mexico City´s residential areas by generating energy through a circular model?

The research presented an initiative that considered four aspects: (i) Suitable technology; it was chosen after considering specific factors in the residence, namely, space, weather, temperature, among others, showing that a Low-Cost Polyethylene Tube Digester might be a suitable technology for the residence. (ii) Drivers and barriers; showing what are the main obstacles that could make the initiative impossible, these were found to be, budget limit, low inhabitants' participation in waste separation activities, and electricity supply after its generation; as well as the key factor(s) that may enable the implementation of the initiative. (iii) Circular business model; it presented the main characteristics to be included to present an attractive project for the stakeholders. These characteristics were, cost of materials for the technology, its operation, financial benefits and investment, and insurance. Finally, (iv) Self-organization as the main driver for implementation.

Each of them added value to successfully plan a potential initiative that is efficient on reducing *Casa de Campo´s* organic waste residuals ending up in landfills or city´s disposals, as well as harmful emissions that come with it, by providing an effective use which will also benefit the residence with energy supply.

Recommendations

Further research must be carried out in order to find a better financial strategy regarding the households that did not showed interest in being involved. Furthermore, the energy supply from the biodigester is another big barrier as mentioned above. The following recommendations are then suggested:

- Consider the possibility of forming a committee within *Casa de Campo*, specific for the initiative, in which only households involved will participate.
- Contemplate the technology for common areas use only, facilitating the supply given that the biodigester would be located in the same area of consumption.

- Take into account the possibility of installing more than one biodigester, one for every 10 houses for instance, this though, would require a higher financial investment to be considered in the strategy.
- To achieve self-sustainability, regulations, both external and internal, will have to be enforced.

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Appendices

Appendix A)

Survey 1.

The survey was originally in Spanish, however, the version presented in this thesis is a translation to English.

Waste to Energy Initiative

1. In case there was the option of installing a system for organic waste treatment: Would you agree on paying a rise in the maintenance fee? *(Waste treatment is carried out through an anaerobic biodigester that processes organic waste generating biogas with which energy can be generated in the form of electricity for domestic use, in addition to reducing waste volumes and emissions. By generating electricity, in the long-term electricity quotas could be reduced, and with the reduction of garbage volumes, the number of days that the garbage truck would need to collect the waste could be reduced, reducing maintenance fee).*
   - YES
   - NO

2. If your answer was YES, select the choice that best fits the amount that you will be willing to pay?
   - $ 100.00 MXN pesos - $ 300.00 MXN pesos
   - $ 301.00 MXN pesos - $ 600.00 MXN pesos
   - $ 601.00 MXN pesos - $ 1000.00 MXN pesos
   - $ 1001.00 MXN pesos - $ 1500.00 MXN pesos
   - Other (specify)

3. Select the option that corresponds to what you consider a benefit of investing in an initiative of these characteristics:
   - Reduction in electricity payment
   - Better waste management
   - Reduction in transportation costs (waste truck)

- Environmental benefit
- None of the above

4. If you selected "None of the above", please provide an answer that corresponds to the benefit:

5. If you are not convinced, select the option that corresponds to what you would "need" for you to be involved in an initiative of these characteristics:
   - Confirmed collective action from the whole residential area
   - A socio-institutional coalition.
   - An opportunity niche
   - The option of the initiative to scale
   - None of the above

6. If you selected "None of the above", please provide an answer that corresponds to what you would "need" to me involved:

<u>Appendix B)</u>

Interview with *Casa de Campo*´s Administrative, Ms. Garduño.

The interview was carried out in Spanish, so the questions and answers presented here are a translation from the original language. Before the question and answer session, the interviewee carefully read the consent form and had the time to ask questions regarding the research and its participation on it, which were successfully answered.

1. Are there any regulations for waste separation?

   The local government has regulations for the garbage truck that picks up the waste for organic and inorganic separation, however these are not fully enforced. Recently they (local government) also sent a letter asking that inside the residential area, residents should engage in an organic and inorganic waste separation.

1.1. The regulation also includes types or divisions for waste separation?

The letter sent to the residential area included four different waste categories and corresponding days in which each category would be picked up by the truck.

1.2. If that is the case, is there any sanction for not compliance?

Only petitions and asking them to comply, but the residence´s committee (conformed by residents) has not yet reached an agreement for any sanction.

2. Is there any regulation from the local government regarding waste separation?

   The regulation includes a calendar indicating the days in which each waste category will be picked up, but there are no economic sanctions or of any kind. The garbage truck knows that they have to pick up the waste on the days marked by the local government, but they do not follow these indications, and this causes that residence inhabitants do not respect the days as well, disposing their waste any day its needed.

3. Are there any requirements from part of the local government for any technology installation?

   There are no specific requirements if it is done inside the residence, as being a private community, they only engage in petitions as the ones regarding waste separation.

4. The garbage truck, is it hired directly from *Casa de Campo* or is it provided by the local government?

   The truck is provided by the local government, but they are only allowed to pick up waste bags from the sidewalks or avenues next to the households, so in the case of *Casa de Campo*, administration and committee reached an agreement with the truck in which they are paid extra for them to enter the residence and pick up the waste directly from the waste disposal inside. This extra payment is possible because of the monthly maintenance fee.

5. Regarding electricity regulations in *Casa de Campo*, is it possible that it produces its own electricity?

It is completely possible that the residence produces its own electricity, in fact, not long ago, it was considered installing solar panels to supply electricity for *Casa de Campo´*s common areas, it wasn´t possible because the costs were over the budget.

6. Considering the possibility of installing a technology for waste treatment, could the current disposal space be adapted for its placement?
   *In this question, the interviewee asked a few questions about the operation and construction of the biodigester to provide a more complete answer.
   The main obstacle in this case would be not installing the biodigester but to supply the biogas to each house, which would pose a situation in which an infrastructure job would be required, a more feasible option would be to do it for common areas so the biodigester is located exactly on the supply area or installing one biodigester for every specific number of houses, this would make the biogas supply easier and the whole initiative more feasible.

   6.1. In the case of its operation, do you consider that the two maintenance employees could be trained for operating the technology?
   *To answer this question, the interviewee asked specifically about the operative requirement of the technology, because currently the workload is high and the residence´s expectations are not being met regarding maintenance.
   Maintenance workers could add the biodigester´s operation to their activities.

7. Which are the barriers you consider could keep the installation and operation of this type of technology from being successful?
   Mainly it would be about the installation of the technology, specifically about the biogas supply, given that it is not allowed to have exposed pipelines inside the residence so probably am infrastructure job would be needed.

Appendix C)

Interview with *Casa de Campo* maintenance employee, Mr. Martínez.

The interview was carried out in Spanish, so the questions and answers presented here are a translation from the original language. Before the question and answer session, the interviewee carefully read the consent form and had the time to ask questions regarding the research and its participation on it, which were successfully answered.

1. Approximately, how many households in *Casa de Campo* make a waste separation?
   From the ninety houses, approximately half of them, around fifty, separate their waste, the rest mix everything together.

   1.1. From the households that make a separation, in how many classes is this separation presented?
   It is only separated in organic and inorganic.

2. After waste collection, is it still necessary to make a separation?
   The bags that have mixed waste are left like that. We spoke with the people from the garbage truck, and they make the separation afterwards if needed. Only in some cases we separate, for example, on organic waste bags that have a plastic or any inorganic residual, then it is removed and placed in an inorganic bag.

3. If there is data available, what is the amount generated daily/weekly of organic waste?
   There are variations, for instance, Mondays are usually the days where more waste is collected and for Saturdays there is already an important decrease to almost half the waste, approximately from 100kg to 50kg from the beginning to the end of the week.

4. Do you believe that, if there were a technology application for waste treatment, your work conditions as well as efficiency of waste management in *Casa de Campo* would improve?
   I believe so because this would mean a better control over the waste. Currently there is a lack of respect from some households towards waste separation.

5. Which are the main barriers (if there were any) for the installation of waste treatment technology?

The committee is the main body to authorize these initiatives, so the first step would be to get their approval or green light to then start planning with the administrative person of the residential area. More than a barrier, a series of steps must be followed to successfully carry out the project.

External to the residential area, the garbage truck workers get an income from selling the waste, which after picking up they select for selling, and possibly there would be some pressure from their part to keep having access to the waste.

5.1. Which are the main barriers you identify for an efficient organic waste separation?

From my point of view, it derives from a lack of education or respect because it is a matter of common sense knowing that you have to separate your waste.

5.1.1. In this regard, are there any sanctions from the residential area for not separating the waste?

There are no sanctions, they have only been asked through written documents as well as phone calls or e-mails to do a waste separation, but people are not interested or simply do not care about following these petitions. There have been cases in which they even get offended and angry.

6. Will you be willing to receive training for operating a waste treatment equipment (anaerobic biodigester)?

*The participant first asked if there was a specific schedule of operation for the digester that would change his current work times; in this regard the research does not contemplate any modification, only considered their current working periods, to which the participant answered that he would be interested in supporting this project and being involved operating the digester, emphasizing in the fact that first it is needed to get the committee´s approval.

Appendix D)

CFE Electricity Rates *Currency is in MXN $

MONTH	Jan	Feb	Mar	Apr	May	Jun
CONSUMPTION RATE						
Basic 1 kWh - 75 kWh	$ 0,853	$ 0,855	$ 0,857	$ 0,859	$ 0,861	$ 0,863
Intermediate 76 kWh - 125 kWh	$ 1,031	$ 1,034	$ 1,037	$ 1,040	$ 1,043	$ 1,046
Surplus	$ 3,018	$ 3,026	$ 3,034	$ 3,042	$ 3,050	$ 3,058
MONTH	Jul	Aug	Sep	Oct	Nov	Dec
CONSUMPTION RATE						
Basic 1 kWh - 75 kWh	$ 0,865	$ 0,867	$ 0,869	$ 0,871	$ 0,873	$ 0,875
Intermediate 76 kWh - 125 kWh	$ 1,049	$ 1,052	$ 1,055	$ 1,058	$ 1,061	$ 1,064
Surplus	$ 3,066	$ 3,074	$ 3,082	$ 3,090	$ 3,098	$ 3,106

(CFE, 2021)

Appendix E)

Waste Generation Data

	House 1	House 2	House 3	House 4	House 5	House 6	House 7	House 8
Monday	1 kg	4.200 kg	400 gr	3 kg	1.450 kg	500 gr	1 kg	2 kg
Tuesday	1.700 kg	3.100 kg	1.300 kg	400 gr	1.165 kg	500 gr	2.500 kg	2 kg
Wednesday	1.270 kg	3.100 kg	400 gr	1 kg	1.430 kg	500 gr	2.500 kg	1 kg
Thursday	1 kg	2.800 kg	850 gr	400 gr	185 gr	500 gr	2.500 kg	500 gr
Friday	1.350 kg	4.100 kg	400 gr	1 kg	975 gr	500 gr	4 kg	1 kg
Saturday	300 gr	2.700 kg	0 kg	1 kg	160 gr	500 gr	4 kg	2 kg
Sunday	700 gr	4.900 kg	400 gr	400 gr	165 gr	500 gr	5 kg	2 kg

Appendix F)

Interview Consent Forms:

i) Interview with *Casa de Campo´*s Administrative, Ms. Garduño.

Comprendo que la información proporcionada será utilizada para desarrollar los resultados de la investigación y ayudar a contestar la pregunta de investigación.

SI NO

Doy mi consentimiento para que mi nombre sea utilizado para citar en el texto.

SI NO

Comprendo que cualquier información recolectada, que incluya datos sobre mí, como puede ser, mi nombre o dirección, no será compartida con nadie ni utilizada fuera del propósito de esta investigación.

SI NO

Doy mi consentimiento para que la información que proporcione sea archivada con el objetivo de ser utilizada durante la investigación. La información será guardada en el servicio de alojamiento de archivos multiplataforma en la nube: Dropbox. En el cual el único acceso lo tiene el investigador a través de una cuenta de acceso.

Firmas

Alicia Garduño Lugo	17/06/2021	
Nombre del participante	Fecha	Firma

El participante ha tenido la oportunidad de hacer preguntas y confirmo que ha dado su consentimiento libremente.

Alberto Escofet T	17/06/2021	
Nombre del investigador	Fecha	Firma

Datos de contacto:

Investigador: Alberto Escofet Torres, +31 685616490, aescofett@gmail.com

Si tiene preguntas sobre sus derechos como participante de la investigación, o desea obtener información, hacer preguntas o discutir cualquier inquietud sobre este estudio con alguien que no sea el (los) investigador (es), comuníquese con la Secretaría del Comité de Ética de

ii) Interview with *Casa de Campo* maintenance employee, Mr. Martínez.

Comprendo que la información proporcionada será utilizada para desarrollar los resultados de la investigación y ayudar a contestar la pregunta de investigación.

(SI) NO

Doy mi consentimiento para que mi nombre sea utilizado para citar en el texto.

(SI) NO

Comprendo que cualquier información recolectada, que incluya datos sobre mí, como puede ser, mi nombre o dirección, no será compartida con nadie ni utilizada fuera del propósito de esta investigación.

(SI) NO

Doy mi consentimiento para que la información que proporcione sea archivada con el objetivo de ser utilizada durante la investigación. La información será guardada en el servicio de alojamiento de archivos multiplataforma en la nube: Dropbox. En el cual el único acceso lo tiene el investigador a través de una cuenta de acceso.

Firmas

José Angel Martinez Catorino	17/08/2021	José Angel Martinez
Nombre del participante	Fecha	Firma

El participante ha tenido la oportunidad de hacer preguntas y confirmo que ha dado su consentimiento libremente.

Alberto Escofet T	14/06/2021	[signature]
Nombre del investigador	Fecha	Firma

Datos de contacto:

Investigador: Alberto Escofet Torres, +31 685616490, aescofett@gmail.com

Si tiene preguntas sobre sus derechos como participante de la investigación, o desea obtener información, hacer preguntas o discutir cualquier inquietud sobre este estudio con alguien que no sea el (los) investigador (es), comuníquese con la Secretaría del Comité de Ética de la Facultad de Comportamiento, Gestión y Ciencias Sociales de la Universidad de Twente a través de ethicscommittee-bms@utwente.nl y los teléfonos: 053-489-3520 / 053-489-3294.