SOCIAL ACCEPTABILITY OF RENEWABLE ENERGY: EXPLORING COMMUNITY MEMBERS' PREFERENCES FOR ATTRIBUTES OF ENERGY PROJECTS IN THE EL ZANGARRO COMMUNITY, MEXICO

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By

Virginia Lucia Moreno de Quevedo

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Abstract

The primary objective of this study is to assess the social acceptability and community preferences for renewable energy projects in the rural community of El Zangarro, Mexico, using a Discrete Choice Experiment (DCE). The research addresses four central questions: *What is the community's perception of sustainability? How does this perception align with the community's priorities? How do community members evaluate the benefits of alternative energy projects? What trade-offs is the community willing to accept for these projects?*

The study finds that the community perceives sustainability as an important factor, with most respondents recognizing it as essential to addressing local challenges, such as water scarcity, garbage management, pollution and unreliable energy access. Additionally, community members demonstrated that their notion of sustainability aligns closely with their priorities, particularly in improving living conditions through *environmental* management and *financial benefit*s.

In evaluating the *benefits* of alternative energy projects, the results show that the community prioritizes projects that deliver long-term *environmental benefits* while offering significant *financial* advantages. Solar panels and biodigesters were highly favoured, as they address critical community needs like energy security and waste management. Regarding trade-offs, the community is willing to accept moderate *cost* increases if the projects provide clear *benefits* that improve sustainability and living conditions. However, *cost* and *risk* were critical factors in decision-making. Respondents preferred solutions that balance affordability with manageable *risk*s and high *financial* and *environmental benefits,* particularly for solar panels and biodigesters. This research contributes to the literature on rural energy transitions by providing empirical evidence of how community perceptions of sustainability influence renewable energy adoption. It highlights the complex interplay between *financial*, *environmental*, and *social* factors in shaping the acceptability of renewable energy projects. It also could provide a replicable framework for assessing community preferences in rural contexts in Mexico. The findings offer important insights for policymakers and practitioners, emphasizing the need to align renewable energy interventions with local values and ensure *cost*-effective, inclusive implementation. This study significantly advances sustainable energy transitions in rural communities by considering local priorities.

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"Thanks be to God for His indescribable gift!"

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List of Abbreviations

- **CFE** - Comisión Federal de Electricidad

(Federal Electricity Commission)

- **CEPIUG** - Comité de Ética para la Investigación de la Universidad de Guanajuato

(Ethics Committee for Research at the University of Guanajuato)

- **DCE** - Discrete Choice Experiment
- **FIRA** - Fideicomisos Instituidos en Relación con la Agricultura

(Trust Funds for Agriculture)

- **GHG** - Greenhouse Gas
- **IRR** - Internal Rate of Return
- **LP** - Liquefied Petroleum (Gas)
- **MXN** - Mexican Peso
- **NODESS** Nodos a la Economia Social y Solidaria

(Nodes for Social and Solidarity Economy)

- **NPV** - Net Present Value
- **PI** - Principal Investigator
- **PV** – Photovoltaic
- **RE** - Renewable Energy
- **WTP** - Willingness to Pay

CHAPTER ONE

1. Introduction

In rural communities like El Zangarro, access to clean, affordable energy remains a significant challenge. As part of the Environmental effort to eradicate poverty and protect the planet, the United Nations' Sustainable Development Goals (SDGs) emphasize the need for sustainable energy solutions tailored to local contexts. Building on the progress driven by the UN 2030 Agenda for Sustainable Development, a multidisciplinary research group is proposing two renewable energy projects for the rural community of El Zangarro in the center of Mexico. One of the projects produces bioenergy; the advantage of bioenergy energy is that it exploits a resource naturally abundant in a particular environment or the waste from a natural process, providing *benefits* for both the environment and the community (Rahman et al., 2019). The second project generates energy from the sun to produce electricity.

Social acceptance is a cornerstone for the success of renewable energy projects. Initially defined by Wüstenhagen et al. (2007), social acceptance of renewable energy innovation depends on socio-political, community, and market acceptance. This framework is essential to understanding the dynamics that increase the implementation of renewable energy solutions. Recent literature has expanded on this by emphasizing social acceptance's multidimensional and dynamic nature, incorporating factors such as local context and trust (Mancini & Raggi, 2022). This study follows the call from researchers like Sovacool (2014) to integrate social science into energy research by exploring community behaviour, preferences, and trade-offs crucial for sustainable transitions to ensure long-term energy project success. This study responds to his call for interdisciplinary approaches by applying Discrete Choice Experiments (DCE) to assess community preferences in rural Mexico, integrating both techno-financial and social dimensions of sustainability.

A biodigester installation in El Zangarro could provide *environmental, financial, and social benefits*. Anaerobic digestion (AD) is a well-known renewable technology that breaks down organic matter, such as animal manure and food waste, to produce biogas—a renewable alternative to natural gas and liquefied petroleum (LP) gas—and digestate(biol), a valuable fertilizer. Hettiarachchi et al. (2018) discuss the potential of organic waste in developing countries to contribute to sustainable waste management through the production of biogas and compost. They highlight that organic waste (a significant portion of municipal solid waste in developing countries) can be effectively converted into valuable products such as biogas, offering a renewable energy solution and compost, which can support agricultural productivity. Thus, the community could benefit from reduced energy costs, improved *environmental* quality, and enhanced community cohesion and participation. These *benefits* are closely aligned with several of the United Nations' Sustainable Development Goals (SDGs), such as SDG 7 (affordable and clean energy), SDG 2 (zero hunger), SDG 13 (climate action), SDG 11 (sustainable cities and communities), and SDG 6 (clean water and sanitation).

Solar energy is another critical renewable technology with significant potential. Solar energy comes from the sun's rays, which can generate heat, initiate chemical reactions, or produce electricity. Solar photovoltaic (PV) systems transform sunlight directly into electricity and have been widely adopted due to their scalability and decreasing costs. Solar panels offer a sustainable energy source by harnessing sunlight to generate electricity for remote and rural areas, reducing reliance on fossil fuels and contributing to *environmental* sustainability. Solar energy systems could offer the potential for significant financial savings and energy independence for rural communities such as El Zangarro. In a community like the one mentioned before, where access to affordable energy is limited, solar PV systems provide *environmental benefits* and the potential for significant long-term financial savings and energy independence.

Although the scientific literature has identified many *benefits* of creating energy with a biodigester (Hettiarachchi et al., 2018), contextualization is crucial for the optimal application and, consequently, the success and persistence of the project (Mancini & Raggi, 2022). Therefore, a research group from the University of Guanajuato surveyed a sample of the El Zangarro population and devoted its first workshop to learning about the community and its views on related topics regarding sustainable matters. The data obtained from this research provided valuable insights that inspired the direction of this proposal.

While the technical feasibility of biodigesters and solar PV systems is essential for the project, their successful adoption depends on social acceptance (Wüstenhagen et al., 2007; Sovacool, 2014). Using the Discrete Choice Experiment (DCE) to capture community preferences, the project ensures that these technologies align with local values and social norms, thus fostering greater community buy-in. An appropriate research tool is needed to assess the community's preferences and design the project according to their expectations and goals. The DCE method, a non-market stated-preference valuation method (Champ et al., 2017), is optimal for this purpose; it allows the evaluation of the community members' preferences for specific attributes related to the energy project proposals. A thorough *techno-financial* analysis is also essential to provide a solid foundation for the DCE. The *techno-financial* analysis will focus on assessing the energy output potential, financial costs, and long-term *benefits* of biodigester and solar PV systems, ensuring that the attributes tested in the DCE reflect feasible, realistic options for the community. The results of the techno-financial analysis will directly inform the design of the DCE, ensuring that the attributes reflect the most feasible and impactful aspects of the biodigester, and solar PV projects tailored to the community's specific needs and preferences. This analysis evaluates the proposed projects' technical feasibility and financial viability, ensuring that the attributes and levels presented in the choice experiment are realistic and relevant to the community's context.

While the technical feasibility of biodigesters and solar PV systems is critical, the community's acceptance and willingness to adopt these solutions will ultimately determine the project's success. The community acceptance underscores the importance of using DCE to capture the community's preferences and ensure the project aligns with their social and cultural context. Active community engagement is crucial for the success of renewable energy projects. Studies have shown that community involvement and trust in project proponents are critical factors influencing the outcome and longevity of such projects (Duran & Sahinyazen, 2021; Mancini & Raggi, 2022). Engaging youth is particularly important, as they are change agents in their communities (Robson et al., 2019). The project aims to build a strong foundation of community participation and commitment by involving women and youth. Engaging local women and youth fosters social cohesion. It empowers these key groups to act as future sustainability champions, ensuring the community remains committed to the project's success over time. During the community engagement, members will continue learning about alternative bioenergy projects and answering specific questions to determine their willingness to commit to them. Incorporating procedural justice principles (Jenkins et al., 2016), the project ensures that the community is engaged as beneficiaries and active participants in decision-making, establishing a foundation of trust and long-term commitment. By embedding procedural justice into the decision-making process, the project aims to build lasting trust and ensure community members see themselves as co-creators of their sustainable energy future. This approach ensures the community is seen as beneficiaries and active collaborators in decision-making. The Discrete Choice Experiment (DCE) will be carefully designed and applied, establishing the attributes and their levels and laying the foundations for trust and dialogue needed for commitment. Lastly, the results will be analyzed using an appropriate statistical model to ensure the process properly captures the community's preferences. Ultimately, the DCE results will provide a roadmap for implementing bioenergy and solar solutions that align with the community's needs, fostering long-term sustainability and enhancing the well-being of El Zangarro's residents. The DCE results will provide insights into the community's energy preferences and could guide the design of policies that maximize *environmenta*l and *social benefits*, ensuring alignment with community priorities. By integrating social and technical dimensions, this project aims to serve as a scalable model for sustainable energy transitions in rural communities, offering understanding and strategies that can be adapted to similar contexts across Mexico and other developing regions.

1.1 Problem Statement

A 2020 study conducted by the University of Guanajuato in the community of El Zangarro had two main objectives:

To determine the energy potential of a bioenergy project in the community and to assess the community members' perception of the project—its acceptability and willingness to develop and use alternative environmentally friendly energy, such as anaerobic biodigesters, to produce electricity. The study used semi-structured interviews to collect information and obtain community members' social perceptions. The two main objectives of using participatory practices in this 2020 study were to trigger reflections on environmental problems that the community was facing and to study the social relationship among the community members and their attitudes towards the proposed biodigester project. The results of the initial research included the geographical identification of the placement of the biodigester, the feasibility of transporting the residual biomass to the storage place to produce biogas, and the results of energy potential for 120 families, which suggest that the biodigesters will cover 50% of the population's energy requirements(electricity), thus reducing energy poverty (Molina Guerrero et al., 2020) For the second objective, the researchers' data showed that the community members were willing to produce and use this alternative energy. This past study provided helpful insights regarding the community's perceptions and attitudes toward sustainable technologies.

This thesis is built on the members' willingness to adopt alternative and sustainable energy solutions, leveraging the lessons and experience from the 2020 study. This foundation allowed us to explore the current community perception and the potential *benefits* of implementing sustainable technologies, such as biodigesters, in a context where reducing energy poverty remains a key priority.

1.2 Research Question and Hypothesis

The current research, therefore, addresses the following questions:
-What is the notion of sustainability in the community of El Zangarro? How does the community notion of sustainability fit with community priorities? How do community members perceive and evaluate the *benefits* of alternative energy projects? Moreover, what are the trade-offs involved in the alternative project scenarios and community members' preferences for these scenarios?
The central hypothesis is that sustainability and renewable energy will be relevant to the community if it relates to its ultimate goals.

The research aims to understand the community's views on sustainability, priorities, and willingness to adopt sustainable energy solutions. By integrating quantitative and qualitative methods, including questionnaires and the DCE, the study seeks to provide a nuanced analysis of community preferences and trade-offs related to proposed bioenergy projects.

Table 1.1 outlines the core components of the research framework used to investigate the sustainability perceptions and preferences of the community in El Zangarro regarding alternative energy projects. The table connects the research questions with corresponding hypotheses, methods employed to gather data, and the tests used to validate the hypotheses.

Table 1.1. Research Question, Hypothesis, Method and Test

Research Question	Hypothesis	Method	Test
1) What is the notion of sustainability in the community of El Zangarro?	The community perceives sustainability as an important	Questionnaire 1: Q3 Q6, Questionnaire 2: Q6a, Q6b, Q6c, Q31	Most answers (>50%) show that sustainability is important to respondents.
2) How does the community notion of sustainability fit with community priorities?	Respondents connect sustainability issues to community priorities.	Questionnaire 1: Q1 Q2 Questionnaire 2: Q7a, Q7b, Q8a, Q8b, Q24, Q25, Q27	Most respondents (>50%) include sustainability issues among community problems. Most answers (>50%) agreed that the *financial and social benefits* (private and community*)* related to the project alternatives are important.
3) How do community members perceive and evaluate the benefits of alternative energy projects? 4) What are the trade-offs involved in the alternative project scenarios and community members' preferences for these scenarios?	Respondents are willing to accept the trade-offs of sustainability.	Choice-experiments responses	Respondents are willing to pay for project attributes that improve living conditions (project alternatives 2, 3, 4) and sustainability (project alternatives 3 and 4)

1.2.1 Detailed Method for Research Question 1

Next, the questions and methods for answering research question number 1 are explained.

Questionnaire 1

Question 3. How important do you consider protecting the environment and nature?

Very important Q3a, Important Q3b, Moderately Important Q3c.

Question 6. Would you like to have direct water every day in your house? Yes Q6a, No Q6b.

Questionnaire 2

Question 6. How important do you consider that there are fewer flies in the environment (*environmental benefit*)? Very important Q6a, Important Q6b, Moderately Important Q6c.

Question 31. Which of the following do you consider most important in investing the money raised from the project? Community garden, a) Free internet access, b) School maintenance and restoration, c) Improvement of streets and roads, d) As additional income for each family, e) Others (explain).

1.2.2 Detailed Method for Research Question 2

Next, the questions and methods for answering research question 2 are explained.

Questionnaire 1

Question 1. What are the most critical problems affecting your community? Please mention them in order of importance (minimum 3).

Question 2. List in order of importance for you from 1 to 5, with one being the most important. a) Earn money, b) Improve green areas of the community, c) Improve children´s education, d) Improve infrastructure conditions in the community, e) Have a good relationship with my neighbours.

Questionnaire 2

Question 7. How important do you think sewage cleanup is an *environmental benefit* in your community? Very important Q7a, Important Q7b, Moderately Important Q7c.

Question 8. How important do you think reducing bad odours caused by animal manure is in your community? Very important Q8a, Important Q8b, Moderately Important Q8c.

Question 24. What would you be most concerned about using electrical energy produced by the sun? Nothing- Q24a.

Question 25. Do you think your neighbours would use fertilizer on their land produced from animal manure (biol)? Yes-25a.

Question 27. Would you buy cooking gas from animal manure? Yes-27a.

1.3 Purpose and Objectives

The thesis aims to identify the concept of sustainability in the community and examine the fundamental elements that contribute to the success of sustainable community projects. The success of community projects involves technical, financial, and social aspects that depend on several steps addressed in this research. The following analyses conducted for this purpose are:

-The technical feasibility

-The financial feasibility

-The social feasibility

The study conducted a techno-financial analysis of the project solutions and the community members' preferences for these project solutions attributes. Fundamental to the technical project's success was the community's willingness to adopt environmentally friendly methods and be committed to maintaining and protecting the infrastructure.

Understanding community members' preferences over *environmental*, *financial*, *and social benefits* and *costs* will contribute to designing the ideal energy project that responds to the community's aspirations. Additionally, this research aims to uncover the trade-offs the community members are willing to accept and whether people are willing to pay for them. Ultimately, the study seeks to inform how technology and humanity can be brought together to promote sustainable solutions. The impact of this project will strengthen community cohesion and quantify the level of community members' preferences in using renewable energy alternatives to develop strategies to help adopt clean energy technology.

The following diagram (Fig. 1.1) illustrates the research process undertaken; it highlights the interconnections between technical and financial analyses, social feasibility, and the methods used to gather and analyze data (questionnaires and DCE) to answer the research questions and test the hypotheses.

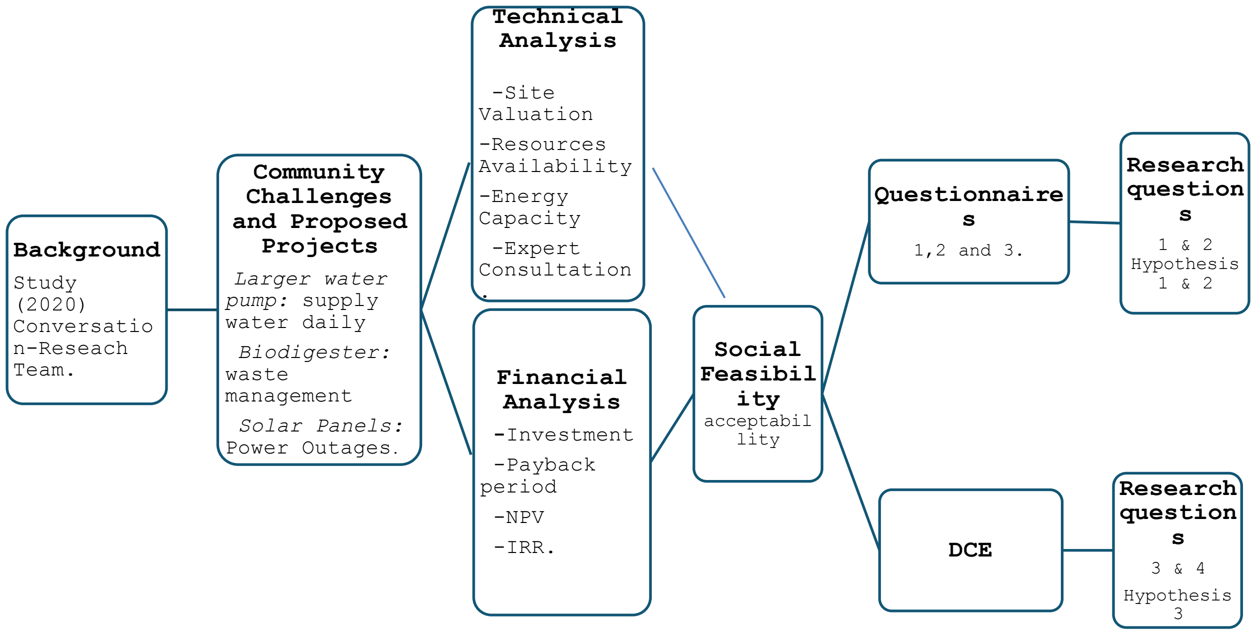


Figure 1.1. Analytical Process Diagram

1.4 Justification

This research is essential for several reasons. First, it addresses the pressing need for sustainable energy solutions in rural communities, which often face challenges in accessing reliable and affordable energy. Second, this study enhances our understanding of how renewable energy technologies can be effectively implemented in these settings by exploring the community's preferences and willingness to adopt bioenergy and solar energy projects. Secondly, the insights from this research will be valuable for policymakers and stakeholders, guiding the factors that influence the social acceptance of renewable energy projects and helping to design and promote similar initiatives in other communities. Additionally, actively involving the community in the decision-making process ensures that the projects align with their needs and preferences, which is crucial for their acceptance and success. Lastly, the comprehensive techno-financial analysis will ensure that the proposed projects are not only environmentally and socially beneficial but also

Financially viable and technically feasible within the community, increasing the chances of successful implementation and long-term sustainability.

1.5 Significance

Socially, this research is crucial for rural communities as it involves them in decision-making, ensuring that renewable energy projects are designed to meet their specific needs and preferences. By considering community preferences, willingness to pay, and the trade-offs they are willing to make, this approach fosters a sense of ownership and commitment, empowering members—particularly women and youth—to take active roles in sustainable development. This action enhances social cohesion and equips the community to engage meaningfully in future projects. By understanding the factors that influence social acceptance of renewable energy projects, this study provides valuable insights for policymakers and stakeholders. These insights can inform policy formulation, improve community planning, and guide the promotion of similar initiatives in other rural communities.

Environmentally, implementing bioenergy and solar energy projects can significantly reduce greenhouse gas emissions and the community's dependence on fossil fuels, contributing to Environmental efforts to combat climate change. The transition to renewable energy will also promote sustainable environmental practices by converting waste into energy or using the energy´s sun, thus benefiting both local ecosystems and the broader environment.

Financially, bioenergy and solar projects can provide cost savings for the community by offering more affordable and reliable energy sources. These projects can create jobs related to installing, maintaining, and producing energy systems while fostering local entrepreneurship by selling bioenergy by-products, such as fertilizer. In the long term, these initiatives can stimulate local economies, providing financial stability and growth for rural communities.

The comprehensive techno-financial analysis this research includes ensures that the proposed projects are feasible and sustainable in the long term. This analysis provides a solid foundation for implementing projects that align with the community's needs and preferences by assessing the energy output potential, financial costs, and overall *financial benefit*s. Additionally, this study will contribute to the academic literature on renewable energy, community engagement, and social acceptance, offering a model that can be replicated in other rural settings.

This research addresses the gap between technological innovation and community needs by promoting sustainable development in rural areas. By incorporating community preferences, willingness to pay, and trade-offs into project design, the study ensures that these projects are technically viable and socially acceptable. The findings from this research will offer a model that can guide the design and implementation of future renewable energy initiatives.

This research has the potential to serve as a pioneering model for evaluating renewable energy projects in rural communities across Mexico. By demonstrating a systematic approach that incorporates community preferences, willingness to pay, and techno-financial feasibility into project design, this study sets a precedent for future projects. The methodologies and findings can guide policymakers and practitioners in developing more effective, accepted, and sustainable renewable energy initiatives, ensuring their success and adaptability in diverse rural contexts. By integrating social and technical dimensions, this project aims to serve as a scalable model for sustainable energy transitions, offering insights and strategies that can be applied in similar settings across Mexico and other developing regions.

CHAPTER TWO

2. Literature Review

The literature review explores the knowledge related to renewable energy projects, social acceptance, community engagement, and the specific technologies of biodigesters and solar energy. This chapter aims to provide a comprehensive background for understanding the context and significance of the proposed research, highlighting key findings, methodologies, and gaps in the current literature.

2.1 Renewable Energy in Rural Communities

Renewable energy projects are crucial for addressing energy poverty and promoting sustainable development in rural areas. Technologies like biodigesters provide reliable and affordable energy, contributing to *environmental* sustainability by reducing greenhouse gas emissions and dependence on fossil fuels (Rahman et al., 2019). Several studies have demonstrated various *benefits* of renewable energy projects in rural settings. For example, Hettiarachchi et al. (2018) highlight the potential of biodigesters to convert organic waste into biogas, reducing reliance on traditional biomass fuels by incentivizing the separation and collection of organic waste. Similarly, Duran and Sahinyazan (2021) discuss solar PV systems' scalability and decreasing costs, making them an attractive option for rural electrification. The reduction in solar panel costs, along with improvements in module efficiency and supportive policies, have contributed to the increased viability of solar technology in off-grid and mini-grid projects. These factors position solar PV systems as a cost-effective and scalable solution for providing reliable energy access in rural areas. In addition, Georgarakis et al. (2021) explored prosumers' preferences for peer-to-peer electricity trading in the Netherlands, emphasizing decentralized energy systems' social and *financial benefit*s.

2.2 Social Acceptance of Renewable Energy Projects

Social acceptance is a critical factor for the success of renewable energy projects. It involves socio-political, community, and market acceptance (Wustenhagen et al., 2007). Factors influencing social acceptance include trust in project proponents, perceived *benefits* and risks, and community involvement in decision-making. Energy Justice provides a crucial lens for understanding these dynamics by emphasizing fairness in the distribution of *benefits* (distributive justice), recognition of marginalized groups (recognition justice), and inclusion in decision-making (procedural justice) (Jenkins et al., 2016).

Recent literature emphasizes the importance of local context and trust in fostering social acceptance. Mancini and Raggi (2022) argue that understanding community-specific needs and preferences is crucial for designing socially acceptable projects. Duran and Sahinyazan (2021) highlight that community involvement and transparent communication are essential to building trust and obtaining support for renewable energy initiatives. The DCE can quantify these preferences, allowing researchers to assess how communities value different attributes of renewable energy projects (Azarova et al., 2019). Moreover, Ek and Persson (2014) conducted a choice experiment in Sweden to measure consumer preferences for wind farm characteristics, revealing the importance of visual impact and location in public acceptance. Similarly, Stigka et al. (2014) reviewed contingent valuation applications to assess social acceptance of renewable energy sources, underscoring the role of perceived *benefit*s and *cost*s.

2.3 Community Engagement and Participation

Community involvement is crucial for the success and sustainability of renewable energy projects. Engaging community members in planning, decision-making, and implementation fosters a sense of ownership and ensures projects align with local preferences. Azarova et al. (2019) demonstrate how DCEs can capture community preferences for renewable energy projects, including environmental impacts, financial costs, and local acceptance. By integrating DCE into project design, researchers can ensure that procedural justice—the fairness of the decision-making process—is respected and that the community feels empowered to influence outcomes (Jenkins et al., 2016).

Engaging youth in sustainable development initiatives is crucial because young people are often the agents of change in their communities, driving innovation and pushing for long-term *environmental* sustainability. As Robson et al. (2019) highlight, youth involvement in rural Mexico is essential for revitalizing community-forest linkages, bringing fresh energy and leadership potential to forest management and local governance. Similarly, O'Brien et al. (2018) emphasize that youth activism is pivotal in addressing climate change, as young people challenge prevailing norms and promote alternative, more sustainable futures. These perspectives underscore that empowering youth is beneficial for their communities and essential for *environmental* progress. Similarly, women's involvement in renewable energy projects is essential for fostering financial empowerment and social cohesion in rural and developing communities. According to Clancy & Skutsch (2003), addressing gender concerns in energy access is crucial for alleviating poverty, as women often bear the burden of energy-related tasks such as fuel collection and household energy management. By integrating women into the decision-making and operational aspects of renewable energy projects, their livelihoods can improve significantly. Moreover, women's involvement in renewable energy projects is crucial for financial empowerment and fostering deeper community engagement and participation. According to Baruah (2015), women play a pivotal role in ensuring the success and sustainability of renewable energy initiatives by contributing local knowledge and acting as intermediaries between the project and the community. Their participation in decision-making enhances the community's acceptance of the project and strengthens social cohesion.

Similarly, Pueyo et al. (2018) emphasize that involving women in renewable energy enterprises leads to more inclusive and sustainable outcomes, as women often assume leadership roles in these projects, thereby increasing the overall engagement of the community. Their research in Ethiopia shows that women's participation in energy initiatives helps mobilize local resources and fosters collective action, which is essential for the long-term success of such projects. Moreover, initiatives like the United Nations Environment Programme's "Powering Equality" report (2020) highlight that women entrepreneurs play a critical role in expanding energy access in rural areas, thereby contributing to the achievement of multiple Sustainable Development Goals (SDGs). Communities can achieve more resilient and equitable outcomes by involving women in all stages of renewable energy projects—from planning and implementation to management and evaluation. Biswas et al.

(2021) discuss the co-production of energy transitions at the grassroots level, emphasizing the need for inclusive and participatory approaches to achieve equitable and sustainable energy solutions. The work of Haque et al. (2021) on socio-cultural acceptance of solar adoption in Mumbai and Cape Town further illustrates the significance of community-specific engagement strategies.

2.4 Technologies: Biodigesters and Solar PV Systems

2.4.1 Biodigesters

Biodigesters are anaerobic digestion systems that convert organic waste into biogas and digestate. Biogas can be used as a renewable energy source for cooking, heating, and electricity generation, while digestate is a nutritious fertilizer. Hettiarachchi et al. (2018) discuss biodigesters' *environmental* and *financial benefit*s, including reducing greenhouse gas emissions, improving waste management, and providing clean energy. Biodigesters can be crucial in promoting sustainable development in rural communities. They highlight the potential of biodigesters to address energy poverty and improve the quality of life for rural residents. However, successful implementation requires careful consideration of local conditions, including feedstock availability, technical capacity, and community acceptance.

Abdullah and Mariel's (2010) research on willingness to pay for improved electricity services using choice experiments highlights the importance of reliable electricity in rural settings. Their study shows that rural households are willing to pay for improvements in electricity reliability. These results suggest that investing in energy infrastructure, such as alternative energy sources, could be financially viable in these areas. Additionally, studies by Khan et al. (2022) on the non-market valuation of aquatic ecosystem services using discrete choice experiments provide insights into the broader *environmental benefits* where participants value *environmental benefits* as reflected in their willingness to pay for improvements in these attributes.

2.4.2 Solar PV Systems

Solar photovoltaic (PV) systems generate sunlight directly into electricity, providing a clean and renewable energy source. The scalability and decreasing costs of solar PV technology make it an attractive option for rural electrification. Mancini and Raggi (2022) discuss the *benefits* of solar PV systems, including their ability to provide reliable and affordable energy, reduce greenhouse gas emissions, and enhance energy security. Solar PV systems can be deployed in various configurations in rural settings, from small standalone systems to larger community-based microgrids. Rahman et al. (2019) emphasize the importance of considering local context and community preferences when designing and implementing solar PV projects. Ensuring technical feasibility and financial viability is critical for their success and sustainability. Georgarakis et al. (2021) highlight the importance of social fairness in peer-to-peer electricity trading, which can be applied to implementing solar PV systems in rural areas. Studies by Will et al. (2022) on consumer preferences for carbon-neutral charging services for electric cars also provide valuable insights into the acceptance of clean energy technologies.

2.5 Methodology for Assessing Community Preferences

Evaluating community preferences for renewable energy projects is essential for designing socially acceptable and sustainable solutions. The DCE method is a widely used non-market stated-preference valuation technique that allows researchers to assess individuals' trade-offs between different project attributes (Champ et al., 2017).

The DCE method presents respondents with a series of hypothetical scenarios, each with different combinations of attributes and levels. Respondents are asked to choose their preferred approach, allowing researchers to determine each attribute's relative importance and individuals' willing trade-offs. This method provides valuable insights into community preferences and can inform the design and implementation of renewable energy projects.

Azarova et al. (2019) used choice experiments to study the social acceptance of renewable energy communities in Austria, Germany, Italy, and Switzerland, highlighting the importance of local preferences and willingness to pay. Similarly, Menyeh's (2021) study of household investor preferences for renewable energy investments in Ghana underscores the relevance of understanding community-specific financial considerations.

The DCE plays a key role in understanding how niche innovations, such as biodigesters and solar PV systems, are accepted by communities within the broader socio-technical system (Geels, 2002). The method allows researchers to measure preferences for various attributes, helping identify the trade-offs communities are willing to make between *cost*, *environmental benefits*, and ease of use (Azarova et al., 2019). These results are particularly relevant in rural settings, where community preferences and social norms significantly influence the success of renewable energy transitions (Geels & Schot, 2007).

2.6 Gaps in the Literature

Despite the extensive literature on renewable energy projects, several gaps remain. First, there is a need for more research on the specific factors that influence social acceptance of renewable energy technologies in different cultural and geographical contexts. Second, while many studies highlight the importance of community engagement, there is limited empirical evidence on the most effective strategies for involving community members in decision-making (Duran & Sahinyazan, 2021; Gaede & Rowlands, 2018). Additionally, the Discrete Choice Experiment (DCE) method is not widely used to assess rural community preferences, particularly in developing countries, indicating a clear need for further exploration. Moreover, comprehensive techno-financial analyses evaluating renewable energy projects' long-term feasibility and sustainability in rural settings are scarce. Such studies are critical for ensuring that renewable energy projects are technically sound, financially viable, and aligned with community needs.

Furthermore, research on the application of DCE in rural settings, especially in developing countries like Mexico, is limited. Local contexts, including social, financial, and cultural factors, play a significant role in technology adoption in these regions. Although studies like Azarova et al. (2019) demonstrate the potential of DCE for assessing community preferences, its application in rural communities remains underexplored.

Additionally, there is a need for more research into the political implications of sustainability transitions and how policies can either facilitate or hinder the adoption of renewable energy technologies in rural areas (Meadowcroft, 2011). Policy frameworks can significantly influence the success of renewable energy projects, particularly in regions where regulatory environments are evolving.

This research aims to address these gaps by conducting a detailed assessment of community preferences and willingness to pay for renewable energy and solar energy projects in the rural area of El Zangarro. By applying DCE and conducting a comprehensive techno-financial analysis, this study will provide valuable insights into the community's needs and inform more effective policy development and project design in rural energy transitions.

2.7 Conclusion

The literature review underscores the critical role of renewable energy projects in promoting sustainable development within rural communities. Rural communities may have unique cultural and social dynamics that influence their acceptance of new technologies. Emphasizing how solutions are designed with an understanding of these cultural nuances can enhance project acceptance. For these projects to be successful, securing social acceptance and actively engaging the community is essential. Understanding the community's needs, values, and preferences is fundamental in designing solutions that resonate with them. Technologies like biodigesters and solar PV systems hold great potential for generating energy, but their success depends on how well they align with local conditions and community preferences. Beyond providing energy, technologies like solar PV and biodigesters can also create jobs, encourage local entrepreneurship, and reduce energy costs, making the projects more attractive to the community.

This research seeks to enhance the effectiveness and sustainability of renewable energy projects in rural Mexico. It emphasizes the importance of directly consulting the community to understand their needs and priorities. By involving the community throughout the decision-making process, the projects can be tailored to meet their genuine expectations, fostering more substantial acceptance and ensuring long-term sustainability.

Additionally, this research strongly emphasizes the social dimensions of renewable energy projects. By focusing on community engagement and inclusion, the study aims to develop solutions that provide clean energy and align with the socio-cultural context of rural communities, promoting both *environmental* and social sustainability.

CHAPTER THREE

3. Methodology

3.1 Personal Statement of Positionality

I am a Catholic housewife and mother of two daughters. I have a background in food engineering and belong to the middle class in Mexico. My brown skin tone and deep-rooted Catholic faith significantly influence my interactions and understanding of the community I study.

As a committed Catholic, I uphold the values of preserving family heritage, principles, and beliefs, viewing the family as the cornerstone of society. My shared religious background with the predominantly Catholic community I engage with fosters mutual values and facilitates meaningful connections.

My practical knowledge as a wife and mother provides insights into typical energy costs for Mexican families. However, I acknowledge that my gender may pose challenges in communicating with male community leaders, though my research group includes male colleagues who can help mitigate this issue.

My education in food engineering has ingrained in me a structured and scientific approach to problem-solving. Recognizing my need to grasp social concepts better, I plan to collaborate with a social science researcher to address the social dimensions of my research effectively. I will also remain attuned to the project's expectations, enabling me to objectively assess the community's needs. In rural Mexico, community leaders often trust individuals with academic credentials, which can facilitate cooperation. Thus, I approach my research with humility and respect, actively involving community members and leaders to ensure their commitment and trust.

Although I am not a member of the community I study in, my brown skin tone can help establish a sense of connection and trust. My shared physical characteristics also help to create connections and build confidence.

In summary, my personal and professional background, coupled with an understanding of the community’s values and needs, uniquely positions me to conduct this research. I am dedicated to approaching this work with humility and respect, ensuring the community's voice is heard and their needs are addressed comprehensively.

3.2 Background Study (2020)

In 2020, a group of researchers conducted a multidisciplinary study to evaluate the community's eligibility for a sustainable energy project. The study considered financial and social factors, among others, and assessed potential biomass resources. A multiple-choice questionnaire was applied during the research to explore how the community understands bioenergy, their perception of the actual situation, and their willingness to approach it (Molina Guerrero et al., 2020).

This research provided helpful information about the community's perceptions and attitudes towards sustainable technologies.

3.3 Description of the Population

3.3.1 Location

The project was developed in the El Zangarro rural community in Guanajuato State, Mexico. The community is now known as El Zangarro Nuevo since it used to be in the valley where the La Purisima dam is now located (the old community was called El Zangarro). The town is situated at a longitude of 101°16'19.779 W and a latitude of 20°51'28.215 N, at an altitude of 1,880 meters above sea level.

3.3.2 History and Population Characteristics

El Zangarro Nuevo (referred to in the rest of the text as simply El Zangarro) is a relatively new community, not only because it was newly established but primarily because members formed the latest settlement from other communities. Therefore, its social structure has changed from what it used to be.

According to data from the National Institute of Statistics and Geography (2020), El Zangarro has a population of 1,597 inhabitants and 421 households. The population consists of 810 women and 787 men. Most of the inhabitants (95%) are Catholic. The literacy rate is relatively high, with an average education level of 8.08 years, although 7.14% of the population is illiterate, including 56 men and 58 women. Most households have essential services such as electricity (99.71%), piped water (97.05%), and internet access (26.55%).

3.3.3 Educational and Health Services

El Zangarro has a kindergarten, primary, middle, and high school. Students from neighbouring communities such as El Coyote, El Sauce, Del Chapín, San Pedro, and El Charco attend this high school. The community also has a health center near the central plaza, providing essential medical services and programs focused on public health and prevention. Despite these services, common health problems and access to specialized medical care remain areas for improvement.

3.3.4 Political and Administrative Representation

The municipal delegate serves as the community's political and administrative representative, managing local affairs, coordinating with municipal authorities, and addressing residents' needs and demands. Also, within El Zangarro, a water commission manages all well, water, and distribution matters.

3.3.5 Essential Infrastructure and Public Services

El Zangarro relies on a water well that supplies the entire population, and all residents depend on electricity from the power grid. El Zangarro has waste management services and access to emergency services such as fire and police. The communication infrastructure includes mobile phone coverage and internet services, although internet access is available in a smaller percentage of households. A bus service is available to residents, providing transportation to major nearby cities such as Guanajuato and Irapuato. Efforts are being made to improve local infrastructure, such as roads and public transportation, to enhance connectivity with neighbouring regions.

3.3.6 Employment and Social and Financial Challenges

The employed population over 12 is 41.01%, with employment rates differing between men

(55.15%) and women (27.28%).

The community faces several social and financial challenges, including poverty, migration, unemployment, and social issues. Environmental issues such as water pollution and waste management are significant challenges the community faces through various initiatives.

3.3.7 Recreational and Cultural Activities and Heritage

Recreational activities and cultural events are integral to community life. The community has a plot of land designated for playing soccer and a downtown area where the church and the kiosk are located, which serves as a gathering place for residents. The community *benefits* from rich, active participation in local traditions and festivals, contributing to a strong sense of community identity and social cohesion.

3.3.8 Local Economy and Government Projects and Local Policies

The local economy primarily centers on agriculture, livestock, fishing, and employment in nearby companies. Local markets and shops support these activities. The community has two tortilla shops, convenience stores, a church, and small businesses renting furniture and machinery.

El Zangarro is involved in several government projects to improve infrastructure and services, and local policies are designed to enhance residents' quality of life. The municipal delegate plays a crucial role in ensuring that the community's needs are met and that effective coordination with higher levels of government occurs.

3.4 Identified Problems and Its Possible Solutions

The community of El Zangarro faces significant challenges related to its water supply, electricity reliability, water sanitization, and cattle manure on the streets. These issues impact daily life, health, and overall quality of life, making addressing them with sustainable and practical solutions essential.

3.4.1 Water Supply Issues

Currently, the community has access to tap water only every other day. El Zangarro is divided into sections A and B, each receiving water on alternate days. This arrangement is due to the limited capacity of the existing water pump, which cannot supply sufficient water to both sections simultaneously.

When both valves are opened to feed the pump, the distant parts of the community experience inconsistent water flow, often receiving water mixed with air. As a result, the water commission decided to provide water to only one section of the community at a time on alternate days. This action ensures that the water supply for each section is more consistent, albeit limited.

The water commission is acutely aware of the need to conserve water, and this consideration plays a significant role in justifying the limited water supply schedule. Despite these measures, community members have expressed concerns to the delegate and water commission about the adequacy and reliability of the water supply. The restricted access to water affects daily activities and the overall quality of life, highlighting the urgent need for a sustainable solution to improve water distribution and availability.

Community Feedback

Inconsistent Water Supply: Residents in the more distant parts of the community report receiving water inconsistently, with water often mixed with air, making it difficult to carry out daily tasks.

Water Conservation: While the Water Commission emphasizes the importance of conserving water, community members are frustrated by the current system's inefficiencies.

Limited Access: The alternate day water supply schedule limits residents' access to water, impacting hygiene, cooking, and other essential activities.

Impact on Community Life

Daily Inconvenience: The alternating water supply schedule disrupts daily life, making it challenging for residents to plan their activities.

Health Concerns: Limited access to water can lead to hygiene issues and potential health risks, especially in households with children and elderly members.

Financial Impact: The unreliable water supply affects backyard agricultural activities(gardens) and livestock management, which are crucial for the community's economy.

Proposed Project: A larger water pump

The current pump does not have enough pressure to supply the entire community with water daily. Therefore, it is proposed that the pump's capacity be increased and all necessary technical modifications be implemented to ensure a reliable and consistent daily water supply for the entire community.

3.4.2 Electricity Reliability Issues

El Zangarro relies solely on the power grid for its electricity needs. This dependency becomes problematic during strong winds or storms, which often result in power outages. The Comisión Federal de Electricidad (CFE), responsible for maintaining the electricity supply, frequently delays fixing these issues, leaving the community without power for extended periods.

Community Feedback

Frequent Outages: Strong winds and storms frequently cause power outages, disrupting daily life and essential services.

Delayed Repairs: The CFE often takes a long time to repair the outages, exacerbating the inconvenience for community members.

Dependence on the Grid: The community's sole reliance on the grid for electricity makes it vulnerable to these disruptions.

Impact on Community Life

Daily Disruptions: Power outages interfere with daily activities, including cooking, heating, and using electronic devices.

Safety Concerns: Lack of lighting during outages poses safety risks, particularly at night.

Financial Impact: Businesses and agricultural activities that rely on electricity are adversely affected, leading to monetary losses.

Proposed Project: Solar Panels

The proposal suggests installing solar panels to power the existing water pump to reduce the community's dependence on the CFE and improve the reliability of the electricity supply. This approach would ensure the community has a reliable and consistent water supply, as solar power would energize the pump rather than rely solely on the grid.

3.4.3 Water Sanitation and Livestock Waste

Another significant problem in El Zangarro is the presence of flies due to livestock manure. Sometimes, the manure is left on the streets, sidewalks, or the property´s backyard. This issue affects not only those who keep livestock within their properties but also their neighbours and the community. When animals are taken out to pasture, they leave manure on the streets, exacerbating the problem. Wastewater sanitation is another concern for the community. Since no water treatment plant exists, all the waste goes into small water streams or directly into the soil, often used for agriculture.

Community Feedback

Fly Infestation: Residents report a significant presence of flies due to manure, which affects their quality of life and hygiene.

Manure Management: Livestock owners struggle to manage manure effectively, leading to sanitation issues.

Impact on Community Life

Health Concerns: The presence of flies and unmanaged manure poses health risks, including the spread of diseases.

Quality of Life: The fly infestation and odour from manure reduce residents' overall quality of life.
Environmental Impact: Improper livestock waste management can lead to environmental pollution, affecting soil and water quality.

Proposed Project: Biodigester

A biodigester system is proposed to address the issue of manure on the streets and the associated health risks. This system would use the manure from livestock to generate biogas, which households can use for cooking and biol that can be used as fertilizer for crop fields. A census of farmers is conducted to determine the amount of manure available for gas generation.

3.4.4 Addressing the Problems

Addressing these water supply, electricity reliability, and sanitation issues is essential to improving the quality of life in El Zangarro. The proposed solutions—implementing a larger water pump, installing biodigesters, and setting up solar panels—aim to provide a more reliable and consistent water and electricity supply and improve waste management practices to meet the community's needs.

3.5 Methodological Approach

3.5.1 General Methodological Approach

This research employed a comprehensive methodological approach to evaluate the feasibility of implementing non-sustainable and sustainable technologies in the community. The approach integrates technical, financial, and social analyses to assess the proposed solutions comprehensively.

Technical feasibility

Purpose: To assess the technical feasibility of implementing a community's larger water pump, biodigesters, and solar panels.

Process: This involved site evaluation, resource assessment, and determining technical specifications to ensure the proposed technologies can be effectively integrated with the existing infrastructure.

Financial feasibility

Purpose: To evaluate the *cost-benefit* aspects of the proposed technologies.

Process: This included estimating the initial investment costs, operational costs, and potential *financial benefit*s. Financial viability was assessed through the Payback Period, NPV and IRR calculations.

Social feasibility

Purpose: To determine the community's preferences, trade-offs, and willingness to adopt the proposed technologies.

Process: This includes a focus group to tweak three questionnaires and a Discrete Choice Experiment to capture the community members' preferences and trade-offs. The research primarily utilized a mixed-methods approach, incorporating quantitative and qualitative data collection. The DCE data was analyzed using a mixed logit panel.

Choice Experiment (Levels and Attributes)

A Discrete Choice Experiment (DCE) was designed to understand the community's preferences regarding different aspects of the proposed technologies. This experiment included various levels and their attributes to capture community members' preferences and trade-offs.

3.6 Sampling and Method

The following section includes the method used for technical, financial, and social analysis.

3.6.1 Technical Analysis

The technical analysis assessed the feasibility of implementing a larger water pump, biodigesters, and solar panels in the community. The analysis required systematic evaluations and assessments.

Site Evaluation

Identify suitable locations for each technology and assess space availability, structural integrity, and accessibility. Evaluate sunlight exposure for solar panels and resource availability for biodigesters.

Technical Specifications

Determine each technology's capacity, efficiency, and necessary infrastructure. Ensure compatibility with existing systems and evaluate any necessary modifications.

Integration with Existing Systems

Assess the technical feasibility of integrating new technologies with current infrastructure.

3.6.2 Financial Analysis

The financial analysis evaluated the *cost-benefit* aspects of the proposed technologies. Similar to the technical analysis, it included financial assessments.

Cost Estimation

Calculate each technology's initial investment, operation, and maintenance expenses.

Financial Benefits

Assess potential revenues and overall *financial* impact on the community.

Financial Viability

The Initial Investment, Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period.

3.6.3 Social Analysis

The seven steps to implementing a Choice Experiment were followed:

Step 1- Characterize the Decision Problem.

The rural community of El Zangarro, located in Guanajuato, Mexico, faces some challenges. These challenges include:

Water Supply

The community has access to potable water alternatingly, affecting hygiene, agriculture, and daily activities. The existing water pump system does not provide a daily water supply to the entire community.

Electricity Reliability

The community relies solely on the electricity grid, which leads to frequent power outages, especially during storms or high winds. The grid powers the pump, and this dependency disrupts daily life.

Waste Management and Sanitation

Livestock manure in the streets causes hygiene issues and the proliferation of flies, while untreated wastewater contaminates local soil and water streams.

Given this context, the decision problem addressed in this choice experiment involves determining how community members perceive and evaluate the proposed *benefits* of alternative energy projects, the trade-offs involved in the alternative project scenarios, and their preferences for these scenarios. The objective of the choice experiment is to determine which combination of these attributes and their levels are the most valuable and how these values can influence the acceptance and success of the proposed bioenergy project. The alternative energy projects proposed are:

1) Implementing a biodigester system to manage livestock manure and produce biogas, which households can use as a renewable energy source.

2) The water pumping system upgrade. It will include a larger water pump, ensuring a continuous and reliable daily potable water supply.

3) Solar panels. They should be installed to reduce dependence on the electricity grid and ensure a more reliable power supply for the pump.

Step 2- Identify and Describe the Attribute and Their Levels

For the current project's development, the study by Molina Guerrero et al. (2020) was considered to keep exploring the community's issues. It was essential to first engage with community members and local leaders to understand their concerns and priorities. This exploratory research was done through informal conversations with community members and leaders, including the delegate and the treasurer of the water commission, who was instrumental in shaping the initial design. The following tables show how the attributes and their levels were defined (Table 3.1-3.4)

Table 3.1. Level of Benefits for *Private benefits* (Family Benefits)

Status Quo	**Larger Pump**	**Biodigester**	**Solar panels**
		Level	
Current situation	**LOW**  1) I will have water on hand. 2) I will have free time, no longer gathering water. 3) I will be watering my garden more frequently. Food security. 4) I will get sick less because of having water on hand. 5) I will feel better in body, mind, and spirit. 6) I will have fewer problems with neighbours.	**HIGH**  1)Gas for cooking: 30 families. 2) Less bad smell from manure. 3) Fewer annoying flies. 4) Cleaner streets. Less pollution. 5) Fertilizer for my garden. 6) I will get sick less because of not cooking food. 7) I will get sick less related to flies and manure. 8) Make good use of natural resources. 9) Learn more about how to care for the environment. 10)I will feel proud and better in my body, mind, and spirit. 11)I will have fewer problems with neighbours. 12)There will be less poverty.	**LOW**  1)Free time without worrying about power grid failure. 2) No longer worrying about not having water. 3) Learn more about how to care for the environment. 4) I will feel proud. My community takes care of the planet. 5) I will feel better in body, mind, and spirit. 6) Make good use of natural resources. 7) Reduction of pollution

Table 3.2. Level of Benefit for *Community Benefit*

Status Quo	**Large Pump**	**Biodigester s**	**Solar Panels**
		Level	
Current situation	**LOW**  1)The community will have water on hand for community activities. 2) Free time for community activities. Get sick less. 3) I will feel better in body, mind, and spirit. 4) Have fewer problems with neighbours. 5) There will be less poverty.	**HIGH**    1)Gas for cooking for 30 families. 2) Less bad smell from manure. 3) Fewer annoying flies. 4) Cleaner streets. 5) Less pollution. 6) Fertilizer for common areas, such as parks. 7) I will get sick less because of not cooking food. 8) I will get sick less. It is related to flies and manure. 9)Learn more about how to care for the environment. 10)I will feel proud and better in my body, mind, and spirit. 11)Have fewer problems with neighbours. 12)Greener community. 13)Reduction of food waste to landfills. 14)Creation of jobs in your community. 15)Sale of by-products such as organic fertilizer. 16)There will be fewer poor people.	**MEDIUM**   1)Free time to socialize and enjoy yourself in case of power grid failure. 2) Confidence in the water supply. 3) Learn more about how to care for the environment. 4) I will feel proud. My community takes care of the planet. 5) I will feel better in body, mind, and spirit. 6) Have fewer problems with neighbours. 7) Reduction of pollution. 8) Less poverty.

Table 3.3. Level of Benefits for *Environmental Benefits* and *Risk*.

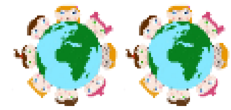
Attributes	Status Quo	Larger Pump	Biodigester	Solar Panels
		Level		
Environmental benefit (Benefits for the planet)	Current situation	**No benefit**	**HIGH**  1)We reduce sending 237.6 tons of CO_2 (harmful gas) to the planet.	**MEDIUM**  1)We reduce sending 55 tons of CO_2 (harmful gas) to the planet.
Risk (Problems that may arise)	Current situation	**LOW**  Water scarcity	**HIGH**  1)Drought. 2) Change of job to earn money. 3) They may move to another place. 4) They may want to use the manure for something else.	**NO RISK**

Table 3.4. Level of Benefits for *Cost* and *Financial Benefit*.

Attributes	Status Quo	Large Pump	Biodigester	Solar Panels
		Level		
Cost (What it will cost me)	Current situation	**LOW**  A monthly payment of thirty-three MXN will be required for four years	**MEDIUM**  A monthly payment of seventy-two MXN will be required for 4 YEARS.	**HIGH**  A monthly payment of one hundred fifty-five MXN will be required for four years.
Financial benefits (What I will earn)	Current situation	**NO BENEFIT**	**MEDIUM**  Approx. 23000 MXN per month for community projects. 20% discount on gas for 30 families. Fertilizer (biol) is at a low *cost* for community green areas and farmers.	**HIGH**  Approx. Twenty-nine thousand MXN per month for community projects.

Step 3- Develop an Experimental Design

After selecting and determining the attributes and levels, the researcher decided on the number of alternatives in each choice set to present to those interviewed. Figure 3.1 presents an example of the choice card.

Figure 3.1 shows an example of the choice cards presented to the community participants.

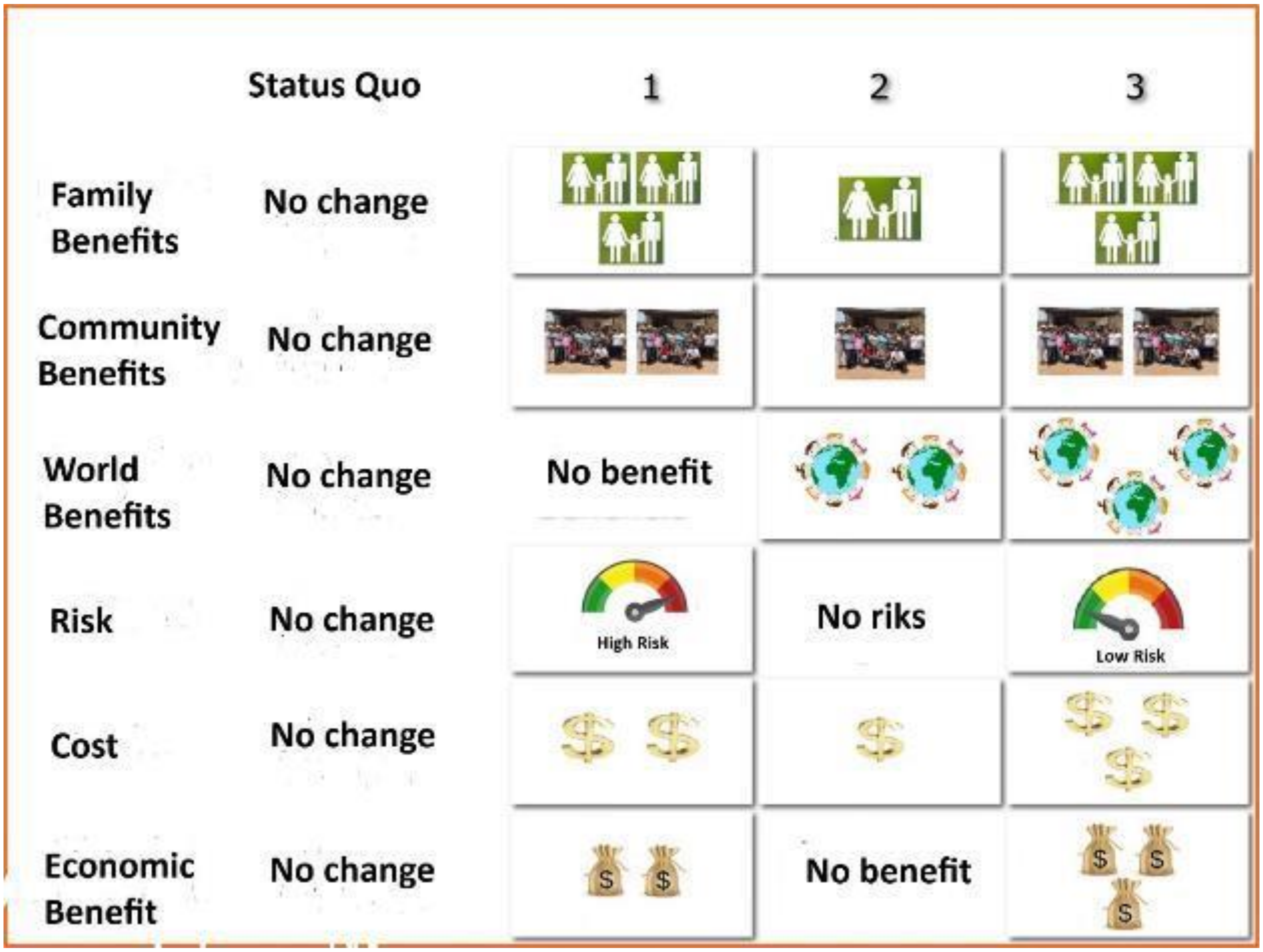


Figure 3.1. Choice Cards

Step 4- Develop Questionnaires

All questionnaires were completed in paper format. Although there was an option to use Survey Monkey for online data collection, it was ultimately not utilized. The decision to use paper-based questionnaires was likely influenced by accessibility for all participants, familiarity with the format, and ensuring a higher response rate among the community members. Three questionnaires were developed for the research. Questionnaires one and two were designed for general participants, while questionnaire three was intended for ranchers to assess their willingness to participate in the biodigester project. This project depends on how much manure they can provide and their willingness to donate it, which is crucial for success.

Step 5 -Collect data.

Focus Group

A focus group was held in the community a week before the workshop to tweak the questionnaires distributed to the community member participants. The focus group included three men and three women. The focus group included two households, two students (University and high school), one rancher, and one farmer, ensuring a diverse representation. During this session, the appropriateness of the language used in the questionnaires was reviewed to ensure clarity and comprehension for all participants. In general, focus groups for a Discrete Choice Experiment (DCE) are conducted to gather feedback on the design and content of the survey, ensuring that the questions are relevant and understandable. Participants are encouraged to discuss their thoughts and provide insights on the attributes and levels included in the DCE, which helps refine the questionnaires.

The Workshop

The target population was community members over 14, emphasizing youth and gender equality. The researcher and the community delegate identified and invited six community members to participate in the focus group. Participants were selected based on their demographics, including age, gender, and occupation, to ensure diversity and representativeness. This approach ensured that the sample included men, women, and youth, representing the general population of El Zangarro.

On Saturday, March 23, 2024, the workshop was conducted at EL Bachillerato SABES El Zangarro, starting at noon and lasting approximately two hours. The research team ensured that the required consent forms, including the minor assent form (if applicable), were signed before the application of the questionnaires (Appendix A and Appendix B). At the beginning of the workshop, participants were encouraged to communicate their doubts and seek clarification. Next, an exploratory questionnaire (Questionnaire One) was distributed to gather information about the community members' main preferences, interests, and expectations. This questionnaire was designed to assess the community's perception and acceptance of sustainable technologies, identify concerns and *benefits*, and determine barriers to implementation to promote sustainable technologies and ensure community support. Participants were given the necessary time to complete the questionnaire (Appendix C).

Following this, a general presentation on biodigesters and solar panels was given, sharing the *benefits* of these projects. After the presentation, a second questionnaire (Questionnaire Two) was administered. This questionnaire evaluated the community's perception and acceptance of the proposed sustainable technologies and their willingness to participate. It seeks to understand the community's concerns and *benefits* with these technologies, identify the main barriers to their implementation, and explore how the *financial benefit*s generated by these projects could be invested for community welfare (Appendix D).

After the second questionnaire, the researcher shared each proposed *project's benefits*, *risk*s, and *cost*s with the community (Table 2.1). Each image in the cards was explained in detail, including its meaning. After presenting the *projects' benefits*, *risk*s, and *cost*s and the details of each image, each choice card was projected on the screen individually (Appendix E). Participants were given sufficient time to mark their preferences on the response sheets (Appendix F).

At the end of the session, the invited livestock farmers were asked to stay and complete a questionnaire (Questionnaire Three). This questionnaire gathered detailed information about the farmers' practices, willingness to contribute manure to the biodigester project, and their expectations and potential contributions (Appendix G). This questionnaire included questions about the current use of manure, the number of cattle, grazing frequency, willingness to participate in the biodigester project, and transportation and contribution of manure. All questionnaires were completed on paper.

Step 6- Estimate model.

The following section details the qualitative and quantitative analysis used in this research.

Quantitative Data Analysis

The number of choice cards was determined using R software with the DCEtool package, considering the number of attributes and their respective levels. R generated the choice sets randomly, ensuring that the distribution of attributes and levels across the choice sets was balanced. This randomization helped create a statistically efficient design. It ensured that each attribute level was presented an appropriate number of times, allowing respondents to make meaningful comparisons between the alternatives presented while minimizing potential biases. The status quo was omitted from each attribute in the design matrix, a standard practice in discrete choice experiments to avoid collinearity between attributes. This omission helped to prevent multicollinearity when estimating the model, ensuring that the coefficients could be interpreted without bias. A mixed logit model was used to analyze the data, as it allows for capturing the heterogeneity of preferences among individuals. A mixed logit panel model using STATA was employed for the choice experiment data. This model is particularly suitable in a context where preferences are likely to vary significantly among community members due to differences in their socio-financial circumstances, age, and perceptions of the presented technologies. The quantitative data from the participants' questionnaire answers was analyzed using descriptive statistics, such as frequencies, to summarize demographic information and questionnaire responses.

Qualitative Data Analysis

The three questionnaires' open-ended, multiple-choice, and explanation responses were analyzed manually. The answers were read carefully multiple times to identify common themes and patterns. These themes were then used to understand the community's perceptions and attitudes better, complementing the quantitative findings.

3.7 Methodological Rigor

This study employed a rigorous approach to ensure the validity and reliability of the results obtained from the Discrete Choice Experiment (DCE). It combined quantitative and qualitative methods and actively involved the community and local leaders.

The attributes and levels selected for the DCE were not solely based on the previous research. There were informal conversations with the researchers who conducted a study in 2020 (Molina & Guerrero, 2020) and the local researcher from the community. These interactions ensured that the selected attributes—*private*, community, *environmental*, and *financial benefits,* as well as *risk*s and *cost*s—were relevant and tailored to the specific needs and challenges of the community. Additionally, informal discussions with local leaders and community members helped validate the attributes, reinforcing their contextual relevance. This participatory approach also ensured that the levels for each attribute were realistic, considering the local socio-financial and environmental context.

The experimental design was developed using the DCE tool in R, with randomization of the attribute and level combinations to ensure a balanced and statistically efficient design. Following best practices for DCEs, the status quo was omitted to avoid collinearity. Sixteen choice sets were presented to participants, providing sufficient data points for robust statistical analysis without overwhelming respondents.

Although the sample consisted of 98 participants, each provided multiple responses, resulting in 1,568 observations, significantly enhancing the dataset's richness. The repeated measures allowed the study to capture shifts in preferences across different scenarios, adding depth to the analysis. While the sample represents approximately 6% of the total population, it was carefully selected to ensure diversity across key demographic variables such as age, gender, and occupation. This approach, combined with repeated measures, provides a robust dataset that captures the preferences and decision-making patterns of the broader community. The smaller sample size was also influenced by resource constraints, which limited the feasibility of surveying a larger proportion of the population. Despite this limitation, the richness of the data, derived from repeated observations, offers reliable insights into community preferences.

The data were analyzed using a Mixed Logit Panel Model, chosen for its ability to capture preference heterogeneity and account for repeated choices in a panel structure. This model allowed for individual variations in preferences, which are critical for understanding diverse community responses to renewable energy projects. Other models, such as standard logit models, were considered but deemed insufficient for capturing the complexity of the decision-making process.

Data quality was ensured through a focus group and a community workshop, which provided opportunities to test and refine the questionnaires. Feedback from these sessions was used to adjust the questions' wording and the choice cards' design, ensuring clarity and relevance. This validation process minimized potential misunderstandings and ensured the survey accurately captured the community's preferences.

The study adhered to ethical standards by obtaining informed consent and ensuring confidentiality for all participants. All data were collected anonymously, and participants were told they could withdraw from the study at any time.

While the methodological approach was robust, the study acknowledges potential limitations. One concern is the cognitive load on participants. Despite efforts to minimize this, some participants—particularly older adults—may have found the task cognitively demanding. Additional measures were implemented to mitigate this challenge and potential cognitive load on participants, particularly among older adults. These included providing clear explanations, simplifying choice sets where necessary, and helping during the data collection. These efforts ensured that all participants, regardless of age or cognitive ability, could engage meaningfully with the Discrete Choice Experiment (DCE), thereby maintaining the rigour and inclusivity of the study.

3.8 Ethical Considerations

All participants signed informed consent before participating in the workshop (Appendices F and G). The data was anonymized and stored securely to maintain confidentiality. The study received ethical approval from the University of Saskatchewan (application ID: Beh 4017) and the University of Guanajuato (Appendix H).

3.9 Limitations of the Study

While there were a few challenges in this study, we took proactive steps to address them, ensuring robust and comprehensive data collection:

Selection of Participants: We made a concerted effort to ensure diversity and representation of the general population in the focus group. For example, facilitating discussion in the focus group involved actively engaging men, women, and youth, which provided valuable insights and helped shape the questionnaires to better reflect the community's needs and preferences.

Data Collection Challenges: Reaching some households and engaging farmers with work and household responsibilities was initially challenging. However, by conducting follow-up visits and being flexible with our scheduling, we successfully included a diverse range of voices in our study, enhancing the richness of our data.

Generalizability: While the findings from this study are specific to El Zangarro, the detailed insights gained can serve as a valuable model for understanding similar rural communities in Mexico. Each community's unique characteristics are highlighted, providing a basis for tailored approaches in future research. Additionally, the technological and *financial* analyses were explicitly based on the proposed projects designed to address some of the issues manifested by this community.

3.10 Validity and Reliability

Several measures were implemented to ensure the reliability and validity of the data collection instruments. The questionnaires were carefully developed and reviewed to ensure clarity and comprehensibility. Feedback from the focus group was instrumental in refining the questionnaires. Throughout the data collection process, the following steps were taken to maintain consistency and accuracy:

Immediate Clarification: If participants had any questions or uncertainties during data collection, we addressed and clarified them immediately. This clarification was possible because the workshop setting allowed for real-time interaction and immediate explanations.

Training of an Additional Person: In addition to the researcher, an additional person was trained to respond to potential questions that might arise while participants were completing the questionnaire. This action ensured that any doubts could be promptly and accurately addressed, maintaining the flow and integrity of the data collection process.

CHAPTER FOUR

4. Results

This chapter presents the findings from the feasibility study conducted in the community of El Zangarro. The chapter comprises two main sections. The first section details the results of the technical feasibility analysis for the proposed larger water pump, biodigesters, and solar panels. The second section examines the *financial* feasibility of these technologies, including *cost-benefit* analyses and *financial* feasibility. For context, the exchange rate at the time of this analysis was approximately 1 CAD=14 MXN, providing a reference for the magnitudes discussed in this chapter.

4.1 Technical Feasibility: Larger Water Pump

4.1.1 Capacity Assessment

The community of El Zangarro is currently using a 40-horsepower submersible pump (Model KOR10400-18) with a motor rated at 40 HP. This motor operates at 460 volts, with a maximum amperage of 59. The pump's capacity is 37.4 BHP max at 60 Hz, with a maximum efficiency point at 209 meters depth and a range of operation between 208 to 800 litres per minute. This information suggests that the pump is suitable for deep wells.

4.1.2 Current Infrastructure Compatibility

To assess the feasibility of upgrading to a larger pump that could provide water to the community daily, the community consulted with the company PERGU. This company has a history with the community because it installed a 40-horsepower pump approximately five years ago (2019) after the previous pump had burned out. PERGU evaluated and recommended replacing the water pump. For the proposed project—a larger water pump that can provide water daily to the community—the following critical factors from the analysis with PERGU need to be considered:

PERGU suggested that while installing a larger 50-horsepower pump was possible, the well's current capacity and water levels must be carefully evaluated to ensure the well can sustain the increased extraction rate without running dry. These procedures involve checking the well's static water level and depth to determine if extending the pipes deeper is necessary to maintain a stable water supply. PERGU also indicated that upgrading to a 50-horsepower pump would require significant modifications to the existing infrastructure. These modifications include:

Transformer Upgrade: To handle the increased power demand, the existing transformer, rated for 40 horsepower, would need to be upgraded to a 75-horsepower transformer. This change is required to prevent overloading and ensure the system's long-term reliability.

Cable and Starter Replacements: The electrical cables and starter equipment currently in place are designed for the 40-horsepower pump. Upgrading to a 50-horsepower pump would require replacing these components to match the new power specifications.

Potential Pipe Extensions: If the well's current depth is insufficient to maintain water levels with the new pump, additional pipe segments may be installed to reach deeper into the well, ensuring a consistent water supply.

The feasibility study conducted by PERGU suggests that upgrading to a 50-horsepower pump is technically possible. However, it requires careful consideration of the well's capacity, significant infrastructure upgrades, and a substantial financial investment. Addressing these factors will be crucial to providing a reliable water source to the community.

4.2 Technical Feasibility: Biodigesters

4.2.1 Site Evaluation

The successful implementation of biodigesters begins with a thorough site evaluation. This evaluation involves assessing the location's suitability in relation to environmental, logistical, and socio-financial factors. The community of El Zangarro has identified a potential site for the biodigester beside an abandoned water treatment plant, which has been out of operation for years. Currently, the community's sewage ends up in fields and a small water stream, leading to environmental concerns. Animal manure would be transported to the biodigester site by truck, possibly every two days.

4.2.2 Resource Assessment

A detailed resource assessment is crucial for determining the feasibility and sustainability of the biodigester project. This assessment will evaluate the availability and consistency of organic waste, water resources, and other inputs.

4.2.3 Organic Waste Availability

Organic waste (manure) from livestock is a key ingredient of a biodigester. A census of cattle heads was completed in 2020 (Molina Guerrero et al., 2020), and the results are shown below (Table 4.1).

Table 4.1 El Zangarro Farmers' Livestock Heads Count in 2020

Number of Ranchers	Bovine	Ovine	Porcine	Unspecified	Total Livestock Head Count
1	10		0	0	10
2	30		0	0	30
3	8		0	0	8
4	32	31	0	0	63
5	0		0	14	14
6	30		0	0	30
7	43		0	0	43
8	0		0	60	60
9	30		0	0	30
10	0		40	0	40
11	30		0	0	30
12	7		0	0	7
13	0		0	12	12
14	0		0	23	23
15	0		0	20	20
Total	220	31	40	129	420

Another census was conducted in February 2024. It was found that 350 heads of livestock were distributed across various breeds, including bovine, ovine, caprine, and equine (Table 4.2).

Table 4.2 El Zangarro Farmers' Livestock Heads Count in 2024

Number of Ranchers	Bovine	Ovine	Caprine	Equine	Total Livestock Head Count
1	6			1	7
2	42			4	46
3	5				5
4	5	10			15
5		20		5	25
6	9		10	6	25
7	4				4
8	38				38
9		20		3	23
10	42			2	44
11	4				4
12	4			1	5
13	6			3	9
14			65		65
15		35			35
Total	168	85	75	25	350

The overall decrease in livestock heads between 2020 and 2024 suggests a downward trend in livestock farming in El Zangarro community. This decline could be related to various factors, including climate change, since the region faces increasingly challenging weather conditions, with reduced rainfall becoming a problem for rain-fed agriculture. As a result, community members may be shifting to other activities or selling their livestock to sustain their livelihoods.

Table 4.3 provides a detailed calculation of the biogas that can be produced daily in the community of El Zangarro based on the different types of livestock available according to the 2024 census. The calculations are based on the biogas production values provided by Varnero and Arellano (1991).

Table 4.3 Calculation of Biogas Produced by Livestock Type in 2024

Livestock Type	Availability per Head (kg/day)	Biogas Volume (m^3/kg wet)	Number of Heads in 2024	Total Biogas Produced per Day (m^3/day)
Bovine (500 kg)	10.000	0.040	168	67.2
Ovine (32 kg)	1.500	0.050	85	6.375
Caprine (50 kg)	2.000	0.050	75	7.5
Total	-	-	-	81.075

Table 4.3 shows that the total biogas produced per day is 81.075 m^3/day under current conditions in 2024.

Manure Availability

All the bovine and caprine manure except equine will be collected. Equine manure contains fibre that can block the biogas pipeline. Because animals graze, it can be challenging to recover all the manure. For this reason, the ranchers must be committed to the project. If porcine livestock were available, 100% of porcine manure would be collected. However, since no porcine exists in the latest census, porcine manure does not fall within the current project scope. The primary focus of these biodigesters will be bovine, ovine, and caprine manure, as these are the most abundant and consistent sources of organic waste in the community.

4.2.4 Technical Specifications

Operational Considerations

A skilled worker from the community should be designated to pick up the manure from those ranchers who cannot deliver it. This worker should also oversee the monitoring, control, and maintenance of the biodigesters. This individual will track critical parameters and gas production to ensure optimal operation and manage regular maintenance, including inspections and cleaning, ensuring the system's reliability and fostering local ownership and capacity building within the community.

System Selection and Sizing

Based on the data from Sistemas.bio, the project will utilize six biodigesters called Sistema 40, which are optimal for handling the manures´ quantity in the community.

Capacity and Production:

Each Sistema 40 can handle up to 235 litres of bovine manure daily, producing approximately 14.7 cubic meters of biogas per day and generating an equivalent of 29.4 kg of LP gas per month.

The six systems combined will be capable of processing up to 1,410 litres of bovine manure daily, producing 88.2 cubic meters of biogas and generating an equivalent of 176.4 kg of LP gas per month.

Comparing the data from Sistemas.bio with our calculations of biogas production based on the livestock data from the 2024 census, we observed that the estimated biogas production (81.075

m³/day) is similar to the capacity indicated by the Sistema 40 units (88.2 m³/day). This consistency reinforces the reliability of our estimates. It suggests that the actual biogas output from the biodigesters in the community of El Zangarro should closely match the predicted values, ensuring that the system is appropriately sized to meet the community's needs.

Water Requirements

The six Sistema 40 biodigesters will require 2,820 litres of water per day. This calculation is based on the standard water-to-manure ratio of 2:1, with each system processing up to 235 litres of bovine manure daily. To meet this water requirement, the community has access to a well that can supply the biodigester system. Additionally, there is the La Purísima reservoir, located approximately 1.5 km from the proposed location of the biodigesters. If additional water is needed, the La Purísima reservoir can serve as an alternative water source, ensuring the continuous operation of the biodigesters.

Additional Infrastructure

The community should build other necessary infrastructure, such as fencing to secure the area, pathways for easy access, and storage facilities for tools and materials. These efforts will help create a safe and efficient working environment for those managing the biodigesters. Another requirement is that if the community brings water from the nearby dam, they must pipe it to the biodigesters.

Consultation with Experts

The company Sistemas.bio was contacted to gather accurate information about the technical requirements, feasibility, and infrastructure needed for this project. Their expertise provided valuable insights and recommendations to ensure the success of the biodigesters in El Zangarro community.

4.2.5 Equivalence to LP Gas and Family Support

Each kilogram of LP gas is equivalent to approximately 1.96 m³ of biogas, and the total daily production of 81.075 m³ is equivalent to approximately 41.37 kg of LP gas per day. If the average family in the community consumes about 1.3 kg of LP gas daily for meals, this biogas production could theoretically support approximately 30 families with their daily cooking energy needs (cooking gas for four hours).

To facilitate the use of the produced biogas, 30 biolungs (portable gas storage units) and 30 bio-stoves will be provided to the participating families. The biolungs, weighing approximately 20 kg, will transport the biogas from the biodigesters to the homes. Participants in the project will be required to visit the biodigester site daily to refill their biolungs with biogas. This system supports the efficient distribution of biogas and encourages active participation from community members directly benefiting from the project.

The 30 biolungs will be allocated to those families committed to continuing their involvement in the project, ensuring that the biogas is used effectively and sustainably within the community.

Biol as a Fertilizer

The biodigester for this project is named Sistema 40. Each Sistema 40 biodigester produces 795 litres of biol daily, a valuable liquid fertilizer. This amount is sufficient to fertilize approximately 29 hectares of land per year. Given the project's scale, 6 Sistema 40 units are proposed. To justify the need for these six units, consider the following calculations:

- Daily Production: Each Sistema 40 produces 795 litres of biol daily. With six systems in operation, the total daily production would be 795 litres/day × 6 systems = 4 770 litres/day
- Annual Production: This equates to 4 770 litres/day × 365 days/year = 1 741 050 litres/year
- Fertilization Capacity: Since 795 litres per day can fertilize approximately 29 hectares per year, the combined production from 6 systems would be sufficient to fertilize approximately: 29 hectares/year × 6 = 174 hectares/year

4.2.6 Alternative Proposal

An additional proposal would be to use the biogas produced by the biodigesters to power a tortilla machine.

Technical Requirements

The technical requirements for this alternative proposal would remain essentially the same, with the critical difference being that bio-stoves and biolungs would not be necessary. Instead, the tortilla machine and specific burner would need to be adapted to create a dual-fuel system that uses LP gas and biogas. This adaptation would ensure the machine can operate seamlessly regardless of the availability of biogas, providing flexibility and reliability for the tortilla production process.

The biodigesters must be located within a maximum distance of 150 to 200 meters from the tortilla machine. This requirement necessitates finding a suitable space within the community that meets both the logistical needs of biogas production, and the proximity needed to power the tortilla machine effectively.

Current Gas Requirements

The tortilla machine requires 1 500 kg of LP gas per month.

- Conversion Factor: 1 kg of LP gas equals 1.96 m^3 of biogas.
- Total Biogas Requirement: 1 500 kg of LP gas × 1.96 m^3/kg = 2 940 m^3 of biogas per month
- Biogas Requirement per Day: 2 940 m^3/month ÷ 30 days = 98 m^3/day

Biogas Production from the Biodigester:

- The biodigester system is estimated to produce 81.075 m^3/day.

Full Capacity Comparison

The biodigester can supply 81.075 m^3/day of biogas, which covers 82.7% of the tortilla machine's daily requirement. The remaining 17.3% must be supplemented by LP gas or additional biogas production.

4.2.7 Treatment of Wastewater and Human Waste

If this issue were to be addressed, wastewater sanitation would be necessary, which is a significant concern for the community. Since no water treatment plant exists, all the waste flows into small streams or directly into the soil, often used for agriculture. Using drainage water would require additional steps:

Gray Water comes from sinks and kitchens and contains detergents and chlorine. It requires initial treatment in a pit to reduce harmful chemicals that could interfere with biological processes. The treatment process for gray water is filtration. The water is filtered into a pit to reduce the load of harmful substances such as detergents and chlorine primarily through settling, dilution, and partial chemical breakdown. This step is crucial to prevent the killing of beneficial bacteria during subsequent treatment stages.

Black Water, primarily from toilets, is less contaminated by harmful chemicals and is directed into a biodigester for further treatment. The black water is processed in a biodigester, breaking down organic matter to produce biogas. Biogas is a mixture of methane (60-65%), carbon dioxide (CO_2), and hydrogen sulphide (H_2S). Due to its corrosive nature, Hydrogen Sulfide (H_2S) found in black water is neutralized using an oxide filter. This action prevents damage to the infrastructure and eliminates this contaminant. The methane produced is then safe to use as a fuel source.

After digestion, the water undergoes a final process, including sand filtration or treatment with aquatic plants such as lilies and reeds. This step helps further reduce pollutants and heavy metals, ensuring the water is safe for certain types of irrigation. The treated water is suitable for irrigating grasses and forages but should not be used for vegetables, as potential bacterial contamination could still pose *risk*s.

Implementing such a sanitation system involves significant costs, potentially as high as reactivating an existing water treatment plant. The separation of gray and black water would need to be implemented at the household level across the community, adding complexity and increasing the costs, making the project less viable.

4.3 Technical feasibility: Solar Panels

The primary project aims to transition the water pump that supplies water to El Zangarro community to operate entirely on solar power, covering 100% of its energy needs. Currently, the pump relies solely on electricity from the grid, with an energy demand of 33 kWp, which translates to approximately 114 230 kWh per year. This initiative aims to ensure full solar power coverage for the pump, reduce dependency on grid electricity, and promote a more sustainable energy solution for the community.

4.3.1 Technical Requirements

System Capacity

To achieve 100% energy coverage, a solar system with a capacity of approximately 65 kW is required. This system would generate an estimated 113.73 MWh per year.

Infrastructure Upgrades

To accommodate a higher energy generation, the contracted demand with CFE (Comisión Federal de Electricidad) would need to be increased. If these requirements are added, the contracted demand could be around 4 000 MXN per kW, potentially totalling 132,000 MXN.

A larger transformer would be necessary to support the increased load from the solar power system, an essential upgrade to ensure the system can handle the total capacity of 65 kW. The current Growatt 30KTL inverter must also be replaced with a larger model to accommodate the increased capacity.

To achieve the necessary capacity, approximately 118 solar panels and an estimated 500 square meters would be required for the system. The identified area on the outskirts of El Zangarro has been deemed suitable for this installation, as it has ample space and optimal sunlight exposure.

The solar panels have a 25-year warranty but require regular maintenance to ensure optimal performance. Maintenance checks should be scheduled every few years, and the first year of operation includes maintenance costs as part of the operational expenses. This ongoing maintenance is crucial to extending the system's lifespan and maintaining energy efficiency.

Even with 100% solar power, the system will remain connected to the grid to ensure continuous operation, especially during periods of low sunlight or higher-than-expected energy demand. This connection provides a reliable backup to maintain the water pump’s operation.

4.3.2 Alternative Proposal

The alternative scenario is to cover 51% of solar power. This system has a capacity of 33 kW, uses 60 solar panels, and generates 58 MWh per year. The existing infrastructure, including the transformer and inverter, is sufficient to support the required level of solar energy generation, meaning no significant changes or additional space are necessary. The system will remain connected to the grid to cover 50% of the water pump's energy needs, ensuring reliability and continuous operation without any interruptions.

4.3.3 Expert Consultation

The company SOLEA has provided these recommendations and data, ensuring that the technical specifications and infrastructure requirements are aligned with industry standards and the community's needs.

4.4 Financial Feasibility: Water Pump

This analysis evaluates the *financial* viability of installing a more extensive water pump in the community and calculates the cash flow projection and payback period.

4.4.1 The Proposed Project

The proposed project involves the installation of a larger water pump in the community, with the primary *benefit* being increased water availability daily throughout the entire week instead of three times a week. This project's financing model is designed so that community members are responsible only for repaying the loan to fund the pump. Once the loan is fully repaid, the community members will have no further financial obligations related to the project. At that point, the project will be considered complete, and the community will continue to benefit from consistent water availability without any ongoing costs associated with the pump. The regular monthly water cost of 80 MXN (electricity and maintenance) per family will continue to be paid, in addition to the surplus for the electricity consumption required to upgrade the water pump.

4.4.2 Assumptions and Rational

Table 4.4 presents the assumptions and rationale for calculating the financial parameters.

Table 4.4. Water Pump: Assumptions and Rational

Parameter	**Value**	**Description**
Number of Families	400	The water commission lists 450 families, but this number has been adjusted to 400 as some families have difficulty paying the water fee.
Monthly Payment per Family	33 MXN	Payments are calculated based on the estimated cost of the water pump and financing terms, ensuring affordability for families.
Annual Interest Rate	20%	The interest rate reflects available credit options, such as the FIRA program, which offers sustainable financing at a fixed rate.
Financing Term	4 years	Financing terms are based on available credit options like FIRA. A four-year term was chosen to balance affordability and *financial* feasibility.
Annual Maintenance Cost	5 000 MXN	Estimates are based on standard maintenance costs for water pumps of similar size and lifespan.
Lifespan of the Water Pump	15 years	Over their lifespan, water pumps provide long-term service to the community.

4.4.3 Initial Investment

Table 4.5 shows the cost of the project.

Table 4.5. Water Pump Project´s Costs.

Concept	**Total Cost (MXN)**
Water Pump, installation, and modifications	350 000.00 MXN
Total Initial Investment:	350 000.00 MXN

4.4.4 Cash Flow Projection and Payback Period

This section calculates cash flow projections and the payback period using the outstanding balance method, ensuring that interest payments decrease annually as the balance also decreases while principal payments increase. Table 4.6 outlines the calculations for Years 1 through 4, where each year's interest is based on the remaining debt. The net annual contribution amount is first used to cover the interest payment, with any remaining funds applied to reduce the principal balance. The payback period debt is approximately 46 months (three years and 10 months), with the debt fully repaid within year 4.

Table 4.6. Water Pump Project Cash Flow Projections (Year 1 to Year 4).

Year	Remaining Debt (MXN)	Interest Payment (MXN)	Principal Payment (MXN)	Total Debt Payment (MXN)	Remaining Debt After Payment (MXN)
1	350 000.0	70 000.0	83 400.0	153 400.0	266 600.0
2	266 600.0	53 320.0	100 080.0	153 400.0	166 520.0
3	166 520.0	33 304.0	120 096.0	153 400.0	46 424.0
4	46 424.0	9 284.8	46 424.0	55 708.8	0.0

4.4.5 Conclusion

Once the loan for the water pump is fully paid off within year 4, the families involved will no longer have to make any further payments. The pump will then continue operating and benefiting the community without additional cost. The monthly cost of 80 MXN per family (electricity fee) will continue to be paid. This monthly fee includes the maintenance cost of the current water pump, which could also cover the larger one if replaced.

4.4.6 Impact on Financial Analysis

The increased electricity consumption from upgrading to a 50 HP pump has not been included in the initial *financial* analysis, as the primary focus was the upfront costs required for purchasing and installing the pump. Since electricity usage can vary depending on factors like pump operation and seasonal demand, excluding these costs from the initial analysis helps prevent potential inaccuracies in the *financial* projections, ensuring a more straightforward assessment. The additional electricity cost, resulting from an estimated increase in power consumption of approximately 10.017 kW, could be factored into the overall cost-*benefit* analysis of the project in future research. This additional cost must be considered if the community decides to have water available daily.

4.5 Financial Feasibility: Biodigester

This analysis evaluates the *financial* viability of installing biodigesters in the community. It considers all associated costs and projected returns over a conservative 20-year lifespan of the biodigesters. The detailed analysis includes calculating cash flow projections, Payback Period, Net Present Value (NPV) and Internal Rate of Return (IRR).

The proposed biodigester project is designed to produce biogas for cooking, meeting the energy needs of 30 community families. Also, the biodigester produces biol, which can be used to fertilize crop fields. The following *financial* analysis provides the daily biogas production meeting the LP gas consumption rate of 1.35 kg per family. This project's financing model is designed so that community members are responsible only for repaying the loan to fund the biodigester project. Once the loan is fully repaid, the community members will have no further financial obligations related to the project.

4.5.1 Assumptions and Rationale

Table 4.7 details the assumptions and rationale for calculating the financial parameters.

Table 4.7. Assumptions and Rationale

Parameter	Value	Description
Number of Families	400	Based on water commission data, this value was adjusted from 450 due to payment difficulties faced by families.
Annual Interest Rate	20%	The rate reflects financing options, like FIRA's fixed rates for sustainable projects.
Financing Term	4 years	The term matches FIRA's standard repayment term for infrastructure loans.
Monthly Payment per Family	72 MXN	This payment ensures affordability based on estimated biodigester cost and financing conditions over four years.
Annual Operation and Maintenance Cost	108 000 MXN	Standard estimates are used to maintain biodigesters and ensure continuous functionality.
Lifespan of the Biodigesters	20 years	The typical lifespan provides long-term value

4.5.2 Initial Investment

Table 4.8 shows the initial costs of the proposed project.

Table 4.8. Biodigester Project´s Costs

Concept	Total Cost (MXN)
Biodigester System (Sistema 40)	275 568.000
BioStove	45 000.00
BioLung	90 000.00
Truck for manure transport	100 000.00
Foundation and first replacement (BioStoves)	90 000.00
Total Initial Investment	600 568.00

The annual maintenance and operation cost is 108 000 MXN.

4.5.3 Net Annual Cash Flow, Projections, and Payback Period

This section calculates the net annual Cash flow, cash flow projections, and payback period using the outstanding balance method. For clarity, two cash flow projections are considered: the first covers the loan repayment plan from year 1 to year 4, and the second covers years 1 to 20, including revenues from the sale of biol and biogas starting from the second month.

The first cash flow projection in Table 4.9 outlines a four-year loan repayment structure with a 20% interest rate. The initial loan of 600 568 MXN will be repaid over four years. The payments will follow the outstanding balance method, where interest is applied to the remaining debt each year.

Table 4.9. Biodigester Cash Flow Projection (Year 1 to Year 4)

Year	Initial Loan (MXN)	Remaining Debt (MXN)	Interest Payment (MXN)	Principal Payment (MXN)	Total Debt Payment (MXN)	Remaining Debt After Payment (MXN)
1	600568.0	600568.0	120113.6	117486.4	237600.0	483081.6
2		483081.6	96616.32	140983.68	237600.0	342097.92
3		342097.92	68419.58	169180.42	237600.0	172917.5
4		172917.5	34583.5	203016.5	237600.0	0.0

For this project, the *total annual income* is 345 600 MXN. This amount is derived from the monthly contributions of 72 MXN from each of the 400 participating families, resulting in 345 600 MXN per year (400 families × 72 MXN/month × 12 months). *The net annual cash flow* is then calculated by subtracting the annual operation and maintenance costs (including one operation worker and necessary inputs) of 108 000 MXN from the *total annual income,* yielding 237 600 MXN. Since this entire net annual cash flow of 237 600 MXN is allocated for debt payments each year, the *net cash flow* remains zero from year 0 to year 4. It will become positive once the loan is fully repaid at the end of year 4. The payback period is four years, considering the family contribution only. This result indicates that the project reached financial breakeven at the end of year four as planned.

Biodigester Cash Flow Projection (Year 1 to Year 20)

The second *cash flow projection* in Table 4.10 outlines years 1 to 20, considering revenues from both biogas and biol (starting from month 2).

Table 4.10. Biodigester Project Cash Flow Summary

Year	Initial/ Remaining Debt (MXN)	Interest Payment (MXN)	Principal Payment (MXN)	Total Debt Payment[1] (MXN)	Additional Expenses [2] (MXN)	Net Annual Cash Flow (MXN)	Remaining Balance [3] (MXN)
1	600 568	120 113.6	117 486.40	237 600	0	297 096.84	483 081.60
2	483 081.60	96 616.32	140 983.68	237 600	0	297 096.84	342 097.92
3	342 097.92	68 419.58	169 180.42	237 600	0	297 096.84	172 917.50
4	172 917.50	34 583.50	203 016.50	237 600	0	297 096.84	0
5	-	-	-	-	0	297 096.84	297 096.84
6	-	-	-	-	0	297 096.84	594 193.68
7	-	-	-	-	0	297 096.84	891 290.52
8	-	-	-	-	45 000	252 096.84	1 143 387.36
9	-	-	-	-	0	297 096.84	1 440 484.20
10	-	-	-	-	100 000	197 096.84	1 637 581.04
11	-	-	-	-	90 000	207 096.84	1 844 677.88
12	-	-	-	-	45 000	252 096.84	2 096 774.72
13	-	-	-	-	0	297 096.84	2 393 871.56
14	-	-	-	-	0	297 096.84	2 690 968.40
15	-	-	-	-	0	297 096.84	2 988 065.24
16	-	-	-	-	45 000	252 096.84	3 240 162.08
17	-	-	-	-	0	297 096.84	3 537 258.92
18	-	-	-	-	0	297 096.84	3 834 355.76
19	-	-	-	-	0	297 096.84	4 131 452.60
20	-	-	-	-	0	297 096.84	4 428 549.44

Note:
1. The total debt Payment remains constant at 237 600 MXN each year, which allows the debt to be fully amortized over four years. This results in a small surplus of approximately 30 099 MXN in the final year.
2. The additional expenses of 108 000 MXN for maintenance and operation costs have already been deducted from the net annual cash flow.
3. The Remaining Balance in the first four years exclusively reflects the debt balance after interest and principal payments and is not related to the Net Annual Cash Flow.

4.5.4 Revenue Generated by the Biodigester

Starting from month 2, the project would generate monthly revenue from the sale of biogas and biol. If only the biogas were sold within the community at a 20% discount from the market price, the revenue from biogas sales would be 19 448.07 MXN per month. Furthermore, for the sale of only 10% of the total biol produced, the additional monthly revenue would be approximately

14 310 MXN (see Appendix I for detailed calculations). The monthly revenue from the sale of biogas and biol would be 33 758.07 MXN. Until the end of Year 4, the family contributions cover the loan repayment, while the revenue from biogas and biol can be considered an additional income for community projects.

4.5.5 Net Present Value (NPV)

The *financial* analysis of the biodigester project was conducted using the Net Present Value (NPV) method to assess its *financial* feasibility. The calculation considers the contributions from community families during the first four years, the revenue generated from biogas and biol sales starting in the second month, as well as the necessary replacement costs for key equipment such as bioStoves, bioLungs, and additional vehicle replacement in year 10. After covering all operating, maintenance, and replacement costs, the project's earnings will be made available monthly to fund additional community projects.

|

General Key Assumptions for the NPV Calculation
Table 4.11 shows the assumptions for the calculation of NPV.

Table 4.11. Assumptions for NPV Calculation

Parameter	**Value**	**Description**
Initial Investment	600 568 MXN	This investment covers the project's installation and equipment costs.
Monthly Contributions from Families	72 MXN/ family	For the first four years, 400 families contribute monthly, generating an annual income of 345 600 MXN.
Biogas and Biol Revenue	33 758.07 MXN/month	Additional income from biogas and biol sales will start in the second month of the project.
Operating and Maintenance Costs	9 000 MXN/month	A monthly deduction will be made to cover the operating and maintenance costs of the biodigesters.
BioStoves Replacement	45 000 MXN/ year	At the beginning of years 8, 12, and 16, 30 biostoves will be purchased,
BioLungs Replacement	90 000 MXN.	At the beginning of year 11, 30 biolungs will be purchased.
Vehicle Replacement	100 000 MXN	The vehicle will be replaced at the beginning of year 10.
Project Lifespan	20 years	The project's typical lifespan provides long-term value
Discount Rate	7%	Sustainability has a 7% discount rate, which reflects lower perceived risk, preferential financing, and long-term social and *environmental benefits*.

All general assumptions apply consistently from year 1 to year 20, including biogas and biol revenue (starting in month 2), operating costs, and scheduled replacements; however, family contributions end after year 4.

The NPV formula used to calculate the *financial* viability is as follows:

$$NPV = \sum_{t=1}^{n}\left(\frac{F_t}{(1+r)^t}\right) - C_0 \tag{1}$$

Where:

- F_t Net Annual cash flow at time t (see Table 4.11)
- r = Discount rate (7% annually)
- t = Time period in years or months (1 to 20 years)
- C_0 = Initial investment (600 568 MXN; see Table 4.9)
- n = Total number of periods (20 Years)

The NPV was calculated using Equation 1, with a 7% annual discount rate over 20 years of 2 546 880.16 MXN. This positive NPV indicates that the project is financially viable, as future cash flows exceed the initial investment, even with replacement costs.

4.5.6 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is a critical *financial* metric to evaluate a project's profitability. It represents the discount rate at which all cash flows' NPV equals zero. Next, a comprehensive breakdown of how the IRR was calculated using the following formula:

$$0 = \sum_{t=1}^{n}\left(\frac{F_t}{(1+r)^t}\right) - C_0 \tag{2}$$

Where:

- F_t Net Annual cash flow at time t (see Table 4.11)
- r = Discount rate (the rate that makes NPV=0)
- t = Time period in years or months (1 to 20 years)
- C_0 = Initial investment (600 568 MXN; see Table 4.9)
- n = Total number of periods (20 Years)

The IRR was calculated using Equation 2 by finding the discount rate that makes the NPV of all cash flows equal to zero. This project's calculation of the IRR is 49.45%, which means it is expected to generate an annual return of 49.45 % over its 20-year lifespan.

4.5.8 Financial Analysis and Community Revenue Potential for the Biodigester

The biodigester project demonstrates strong *financial* potential by supporting approximately 30 families (see Appendix B for detailed calculations) with daily cooking energy and generating consistent monthly revenue. By providing biogas at a reduced price (20% discount on the regular LP gas cost), the project offers cost savings to participating families while ensuring *financial* viability through substantial revenue generation. The revenue generated from biogas and biol will be allocated to community projects, ensuring the entire *community benefits* from the initiative.

With a positive Net Present Value (NPV) of 2 546 880.16 MXN, the project's future cash flows significantly exceed the initial investment of 600 568 MXN, confirming its ability to yield substantial returns over time, even after covering all operating, maintenance, and replacement costs. The Internal Rate of Return (IRR) of 49.45% is driven by community contributions that fully repay the loan within the first four years and by the biogas and biol sales that generate profit.

The project generates consistent cash flows starting from month 2. Although cash flow remains stable over the 20-year project lifespan, the *financial* burden on community members ceases after year 4, as they no longer need to make out-of-pocket contributions for loan repayment. Contributions from 400 families enable the project's four-year payback period. Once the loan is repaid, family contributions of 72 MXN per month cease, and the project no longer requires additional funding.

The biodigester project is financially viable and sustainable, with a positive NPV, high IRR, short payback period, and steady revenue generation. Over its 20-year lifespan, it provides long-term *financial* and *environmental benefits*, fostering community development and resilience.

4.6 Financial Feasibility: Solar Panels

This analysis evaluates the financial viability of installing solar panels in the community, considering all associated costs and projected returns over a conservative 20-year lifespan of the panels. The detailed analysis was based on the monthly amortization of the loan, assuming the interest applied to the outstanding balance; the analysis will include the calculation of cash flow projection, Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period, along with detailed explanations of the formulas used in each calculation.

4.6.1 The Proposed Project

The proposed solar panel project involves each family paying 155 MXN monthly until the loan is fully repaid. Currently, community families pay 80 MXN per month for the electricity bill of the water pump (electricity fee). The proposal is that families will continue to pay this 80 MXN monthly, and the total amount collected from these payments will be used for community projects. With 400 families in the community, the total monthly amount collected would be 32 000 MXN, which could then be allocated to various community initiatives; this is 384 000 MXN annually. If we subtract 15 000 MXN annually for maintenance costs, the net annual cash flow would be 369 000 MXN. This project translates to a net monthly revenue of approximately 30 750 MXN that could be used for community projects.

4.6.2 Assumptions and Rationale

Table 4.12 details the assumption and rationale for calculating the *financial* parameters.

Table 4.12. Assumptions and Rationale

Parameter	**Value**	**Description**
Number of Families	400	Based on water commission data, this number was adjusted from 450 due to families' payment difficulties.
Annual Interest Rate	20%	The rate reflects financing options, like FIRA’s fixed rates for sustainable projects.
Financing Term	4 years	The term matches FIRA’s standard repayment term for infrastructure loans.
Monthly Payment per Family	155 MXN	This payment is based on the total cost of the solar panels and financing terms, ensuring affordability while covering the loan and interest for four years.
Electricity Fee	80 MXN	The fee is 80 MXN/400 families/12 months 348 000 MXN.
Annual Operation and Maintenance Costs	15 000 MXN	These costs are based on industry standards for solar panels, ensuring proper operation and longevity of the system.
Lifespan of Solar Panels	20 years	The typical lifespan provides long-term value.

4.6.3 Initial Investment

Based on the provided information, the total costs associated with the solar panel installation are provided in Table 4.13

Table 4.13. Solar Panel Project´s Costs

Concept	Total Cost (MXN)
Solar Panels	1 472 264.00
Contracted Power Demand	132 000.00
Civil Works (Obra civil)	50 000.00
Total Initial Investment	1 654 264.00

4.6.4 Net Annual Cash Flow, Projections, and Payback Period

This section calculates the net annual cash flow, cash flow projection, and payback period using the outstanding balance method. For clarity, two cash flow projections are considered: the first covers the loan repayment plan from year 1 to year 4, and the second covers years 1 to 20, including the income from the 80 MXN fee for the pump´s electricity.

The first *cash flow projections* in Table 4.14 outline a four-year loan repayment structure with a 20% interest rate. The initial 1 654 264 MXN loan will be repaid in year 4. The payments will follow the outstanding balance method, where interest is applied to the remaining debt each year.

Table 4.14. Solar Panels Cash Flow Projections (Year 1 to Year 4)

Year	Initial Loan (MXN)	Remaining Debt (MXN)	Interest Payment (MXN)	Principal Payment (MXN)	Total Debt Payment (MXN)	Remaining Debt After Payment (MXN)
1	1654264.00	1654264.00	330852.80	398147.20	729000.00	1256116.80
2		1256116.80	251223.36	477776.64	729000.00	778340.16
3		778340.16	155668.03	573331.97	729000.00	205008.19
4		205008.19	41001.64	205 008.19	246 000	0.00

For this project, the *total annual income* is 744 000 MXN. This amount is derived from the monthly contributions of 155 MXN from each of the 400 participating families, resulting in 744 000 MXN per year (400 families × 155 MXN/month × 12 months). *The net annual cash flow* is then calculated by subtracting the annual operation and maintenance costs of 15 000 MXN from the *total annual income*, yielding 729 000 MXN. Since this net annual cash flow of 729 000 MXN is allocated toward debt payments each year, the *net cash flow* remains zero from Year 0 to Year 4.

The total *payback period* for the loan is approximately 40 months. This calculation is based on an annual contribution of 729 000 MXN (equivalent to 12 months of payments) and a final payment of 246 009.83 MXN. By dividing the last payment by the monthly average of 60 750 MXN (729 000 MXN / 12), we find that it covers approximately four additional months. Thus, the loan is fully paid within 36 months plus an additional four months in the fourth year, totalling 40 months.

Solar Panel Cash Flow Projections (Year 1 to Year 20)

The second *Cash Flow Projections* in Table 4.15 outline Years 1 to 20, considering the income from the electricity fee (starting from month 1). Table 4.15 shows the cash flow summary for the 20-year lifespan.

Table 4.15. Solar Panels Cash Flow Summary

Year	**Initial/ Remaining Debt (MXN)**	**Interest Payment (MXN)**	**Principal Payment (MXN)**	**Total Debt Payment (MXN)**	**Additional Expenses [1] (MXN)**	**Net Annual Cash Flow (MXN)**	**Remaining Balance [2] (MXN)**
1	1,654,264	330 852.80	398 147.20	729 000	15000	369 000	1 256 116.8
2	1 256 116.80	251 223.36	477 776.64	729 000	15000	369 000	778 340.2
3	778 340.16	155 668.03	573 331.97	729 000	15000	369 000	205 008.2
4	205 008.19	41 001.64	205 008.19	246 009.83	15000	369 000	0
5					15 000	369 000	369 000
6					15 000	369 000	738 000
7					15 000	369 000	1 107 000
8					15 000	369 000	1 476 000
9					15 000	369 000	1 845 000
10					15 000	369 000	2 214 000
11					15 000	369 000	2 583 000
12					15 000	369 000	2 952 000
13					15 000	369 000	3 321 000
14					15 000	369 000	3 690 000
15					15 000	369 000	4 059 000
16					15 000	369 000	4 428 000
17					15 000	369 000	4 797 000
18					15 000	369 000	5 166 000
19					15 000	369 000	5 535 000
20					15 000	369 000	5 904000

Notes:
1. The additional expenses of 15 000 MXN for maintenance have already been deducted from the net annual cash

flow.
2. The remaining balance in the first four years exclusively reflects the debt balance after interest and principal payments and is unrelated to the net annual cash flow.

4.6.5 Revenue Generated by Solar Panels

Starting from month 1, the project would receive an income from the electricity fee of 80 MXN, which amounts to 32 000 MXN monthly. Until the loan is repaid (within Year 4), the family contributions of 155 MXN are used for repayment.

4.6.6 Net Present Value (NPV)

The *financial* feasibility of the solar panels project was assessed using the Net Present Value (NPV) method. This calculation includes the contributions made by community families during the first four years, the monthly income generated from the electricity fee starting from the first month, and all operating costs. After covering operating, maintenance, and replacement costs, the remaining earnings from the electricity fee will be allocated monthly to fund additional community projects.

Table 4.16. General Assumption for NPV Calculation

Parameter	**Value**	**Description**
Initial Investment	1 654 264 MXN	This investment covers the project's installation and equipment costs.
Monthly Contributions from Families	155 MXN per family	For the first four years, 400 families contribute monthly, generating an annual income of 744 000 MXN.
Family Electricity Fee	33 758.07 MXN/month	Additional income from the family electricity fee will start in the first month of the project, generating an annual income of 384 000 MXN.
Operating and Maintenance Costs	15 000 MXN/month	A monthly deduction will be made to cover the operating and maintenance costs.
Project Lifespan	20 years	A typical lifespan provides long-term value.
Discount Rate	7%	A 7% discount rate for sustainability lowers the perceived *risk* and includes preferential financing and long-term social and *environmental benefits*.

All general assumptions apply consistently from year 1 to year 20, including the electricity fee (starting in month 1) and operating cost; however, family contributions for the loan payment end within year 4.

The NPV was calculated using Equation 1, with a 7% annual discount rate over 20 years of lifespan. The NPV for this project is 1 886 456.37 MXN, which will generate significant present value well above the initial investment, making it profitable. A positive NPV indicates that the project will generate a net present value higher than the initial investment cost, making it profitable. This result suggests that the project will recover the initial investment and generate additional income in present value terms.

4.6.7 Internal Rate of Return (IRR)

The Internal Rate of Return (*IRR*) is the discount rate that equals the NPV to zero. It is calculated using the Equation 2. Based on the Cash Flow Summary (Table 4.15), the solar panel project's internal rate of return (*IRR*) is 18.84%. This high *IRR* indicates that the project is expected to generate significant returns over its 20-year lifespan.

4.6.8 Financial Analysis and Community Revenue Potential for Solar Panels

The solar panels project shows solid financial potential, providing the community with sustainable energy while generating steady annual revenue. Through monthly contributions of 155 MXN per family during the first four years, the project ensures timely loan repayment. After that, the ongoing 80 MXN monthly electricity fee per family can be allocated to community projects. This structure offers immediate cost savings to families and long-term income for communal initiatives.

With a positive Net Present Value (NPV) of 1 886 456.37 MXN, the project's future cash flows exceed the initial investment of 1 654 264 MXN. The Internal Rate of Return (IRR) of 18.84% surpasses the project's discount rate of 7%, indicating a solid financial performance and reinforcing the project's long-term viability.

The project achieves a payback period within year 4, with contributions from 400 families ensuring rapid repayment of the initial loan. The 80 MXN electricity fee per family can be directed toward community development.

The solar panels project is financially viable and sustainable, offering a high NPV, robust IRR, a short payback period, and consistent income generation. Over its 20-year lifespan, it delivers long-term *financial benefit*s, supporting energy needs and community resilience without imposing additional financial burdens beyond the initial investment.

4.6.9 General Financial Feasibility of the Three Projects

Each project within the community's renewable and sustainable energy initiative exhibits unique financial characteristics and potential for community revenue generation (biodigester and solar panels). The following is a summary of each project:

Water Pump Project: The primary objective of the water pump project is to improve water access by increasing pump capacity. financially, this project does not generate income directly; it relies on family contributions of 33 MXN monthly over four years to cover the loan repayment. Once the loan is repaid, community members will no longer have additional financial obligations. As it is intended to meet an essential need rather than generate profit, this project's financial feasibility is demonstrated by its affordability and the community's long-term water security.

Biodigester Project: The biodigester project offers robust financial viability by generating direct income from the sale of biogas and biol. Family contributions in the initial years cover the loan repayment, after which the project becomes self-sustaining. Starting in the second month, revenue from biogas and biol supports operational costs and generates surplus income for community projects. With a positive NPV and high IRR, the project demonstrates substantial long-term financial returns and *environmental benefits*.

Solar Panels Project: This project uses monthly family contributions of 155 MXN for the first four years to repay the loan. However, it uniquely relies on each family's ongoing 80 MXN electricity fee, creating an annual income stream that can be allocated to community projects post-repayment. Although the project's direct revenue is derived from community fees rather than electricity generation, its financial feasibility is solidified through a positive NPV and favourable IRR. The solar panels project enables sustainable energy access and consistent income for future community initiatives.

Both projects are financially feasible, but their revenue structures differ. The biodigester generates direct project-related income, while the solar panels project is funded by an electricity fee, making it sustainable for community development. These initiatives provide significant *benefit*s and demonstrate sustainable financial performance aligned with community resilience and self-sufficiency.

CHAPTER FIVE

5. Results

This section examines the social feasibility, focusing on community perceptions, preferences, and openness to the proposed solutions. The findings offer insight into community needs and the potential impact of these technologies. The following section focuses on interpreting and concluding the questions that address research questions 1 and 2 and hypotheses 1 and 2.

5.1 Results from Questionnaire 1

This introductory questionnaire (Questionnaire 1) was the first to be administered to community members to gauge their baseline knowledge before they received a presentation on solar panels and biodigesters, covering their uses, *benefits*, *risk*s, and costs.

5.1.1 Interpretation of Question 1

This interpretation summarizes the most critical findings from participants' responses on issues affecting their community, as shown in Figure 5.1, Table 5.1 and Tables K1 to K5 (see Appendix K).

Question 1. What are the most critical problems affecting your community? Please mention them in order of importance (minimum 3). Note that this question was formulated as an open-response one to participants in the research.

The summary of the responses is presented below. As shown in Table 5.1, the most frequently cited issue among participants was the water supply (23.62%), indicating severe concerns about access to this resource. Garbage (18.4%) was the second most mentioned issue, underscoring significant waste management challenges. Additionally, stray dogs (9.82%) and pollution (7.67%) were notable concerns.

Participants' initial responses showed that garbage and water (35.23% each) were equally important in the first answers, while pollution (12.5%) was also a significant concern. In the second response, water (36.78%) and garbage (18.39%) were the most frequently mentioned problems, with power (16.09%) emerging as another critical issue. In the third response, frequent responses included stray dogs (13.1%), garbage (11.9%), power (10.71%), green spaces (9.52%), social issues (9.52%), and water (9.52%). In participants' fourth responses, stray dogs (25.58%) were the most frequently mentioned issue, followed by water (13.95%). In the fifth response, social issues (25.0%), green spaces (16.67%), drug addiction (16.67%), and stray dogs (16.67%) occurred in close succession.

Table 5.1. General Frequency Table

Alternative	**Frequency**	**Percentage (%)**
Water	77	23.62
Garbage	60	18.4
Stray dogs	32	9.82
Pollution	25	7.67
Green spaces	20	6.13
Social problems	19	5.83
Power	18	5.52
Street paving	15	4.60
Electric light	14	4.29
Drug addiction	8	2.45
Drought	6	1.84
Drainage	5	1.53
Education and Culture	4	1.23
Money	3	0.92
Transportation	3	0.92
Wildfires	3	0.92
Solar heaters	3	0.92
Lack of support	3	0.92
Health care	3	0.92
Infrastructure	2	0.61
Delegate	2	0.61
Street lighting	1	0.31

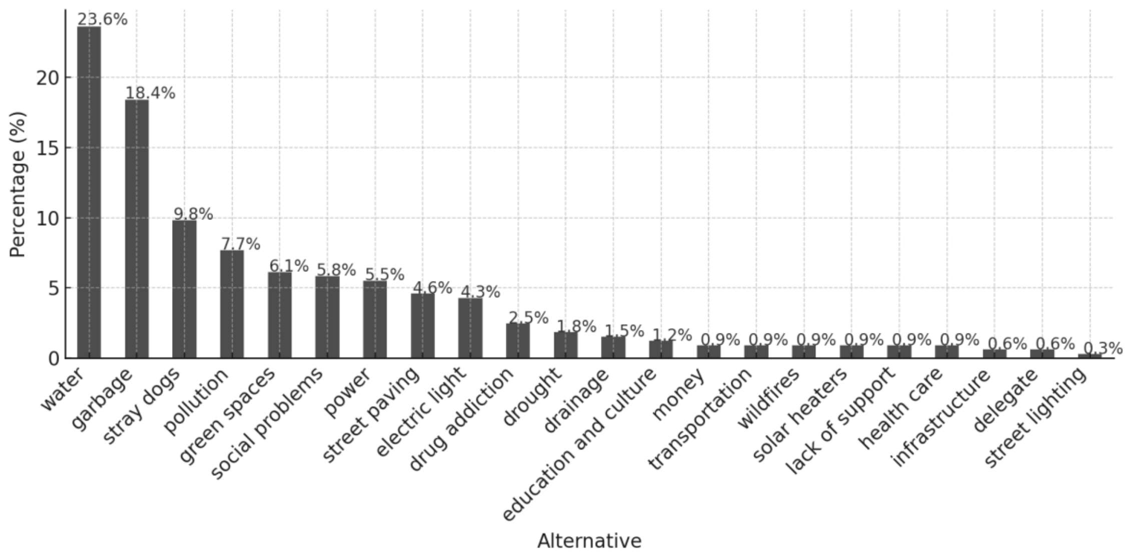


Figure 5.1. General Frequency

5.1.2 Conclusion to Question 1

The community's most pressing issues were water supply and garbage management, with recurring concerns about stray dogs, pollution, and the power supply. These findings highlight the need for targeted interventions to address these critical areas and improve overall community well-being.

5.1.3 Interpretation of Question 2

Question 2. List the following in order of importance for you (earn money, improve green areas, improve children's education, improve infrastructure and have a good relationship with your neighbours), from 1 to 5, with one being the most important. The following interpretation summarizes the participants' responses to their priorities, as shown in Table 5.2. The summary of responses is presented below.

Earn Money: This option received a mixed distribution, with a significant portion (26.14%) ranking it as the most important (1). However, many participants ranked it lower, indicating that while earning money is essential, it is not the top priority for many.

Improve Green Areas of the Community: Many participants rated this highly, with 36.36% ranking it as their second most important priority (2). It received a high overall score (3.61), strongly supporting environmental improvements.

Improve Children's Education: This emerged as the top priority, with 44.32% of participants ranking it as the most important priority (1). It received the highest overall score (4.01), highlighting the community's emphasis on education.

Improve Infrastructure Conditions in the Community: This was moderately important, with the highest percentage (37.50%) ranking it as their fourth priority (4) and an overall score of 2.85. This result indicates a recognized need for infrastructure improvements, but the issue is not as urgent as other priorities.

Have a Good Relationship with My Neighbours: A majority (68.18%) of participants ranked this as the least important issue, reflected in the lowest overall score (1.52). This result suggests that while community relationships are valued, other priorities are more pressing.

Table 5.2. Priorities for Community Improvement

Answer choices	1	2	3	4	5	Total	Score [1]
a) Earn money	26.14%	13.64%	15.91%	22.73%	21.59%	88	3.0
b) Improve green areas of the community	22.73%	36.36%	25.00%	11.36%	4.55%	88	3.61
c) Improve children's education	44.32%	25.00%	20.45%	7.95%	2.27%	88	4.01
d) Improve infrastructure conditions in the community	6.82%	15.91%	36.36%	37.50%	3.41%	88	2.85
e) Have a good relationship with my neighbours	0.00%	9.09%	2.27%	20.45%	68.18%	88	1.52

Note:

1. Scores were calculated as a weighted average, multiplying the percentage of responses for each rank by weight (5 for rank 1 to 1 for rank 5) and summing the results.

5.1.4 Conclusion to Question 2:

The primary focus for the community is improving children's education and green areas while earning money. Infrastructure improvements are also important but to a lesser extent. Building good relationships with neighbours is considered the least urgent priority.

5.1.5 Interpretation of Question 3

Question 3. How important do you consider protecting the environment and nature?

The following interpretation summarizes the most important findings from participants' responses to questions about protecting the environment and nature, as shown in Table 5.3.

Very Important: Most participants (93.18%) considered protecting the environment and nature crucial, indicating a strong community commitment to environmental preservation.
Important: A small percentage (6.82%) of participants considered this issue important, further supporting the community's overall positive attitude towards environmental protection.
Moderately Important, Slightly Important, Insignificant, and I do not know: These options received no responses, reinforcing the community's strong consensus on the importance of environmental protection.

Table 5.3. How important do you consider protecting the environment and nature?

Answer choices	**Responses (%) and Number of Participants**
a) Very important	93.18%,82
b) Important	6.82%, 6
c) Moderately important/ Slightly important/Insignificant/ I do not know	0.00%, 0

5.1.6 Conclusion to Question 3

El Zangarro community prioritizes environmental protection, which most participants consider very important. This strong consensus highlights the community's commitment to preserving their natural surroundings and indicates a supportive attitude towards initiatives aimed at *environmental* sustainability.

5.1.7 Interpretation of Question 6

Question 6. Would you like to have direct water every day in your house?
The following interpretation summarizes the most critical findings from participants' responses on their desire to have a direct water supply daily in their house, as shown in Table 5.4. and 5.5. Most participants (82.95%) strongly desired a daily direct water supply, citing convenience, improved quality of life, and practical *benefits*. They emphasized the importance of having water for daily activities, maintaining hygiene, and reducing the need for water rationing. A smaller group (17.05%) preferred not to have a daily direct water supply, citing water conservation, the sufficiency of current water storage solutions, cost concerns, and environmental considerations.

Table 5.4. Would you like to have direct water every day in your house?

Answer choices	Responses (%) and Number of Participants
Yes	82.95%, 73
No	17.05%,15

Table 5.5. Would you like to have direct water every day in your house? Reasons

Reasons	Subcategories	Comments
Reasons for Yes	Daily Convenience and Necessity	A direct water supply ensures daily water availability, facilitates daily household chores such as cleaning, washing, cooking, and bathing, and provides a reliable and continuous water supply for personal and community needs.
	Improved Quality of Life	It reduces the need to ration water usage, allows for more frequent and efficient activity completion, and helps maintain hygiene and health.
	Financial and Practical Considerations	Consistent payment for water services avoids the hassle of water storage and collection, which is vital for daily living and domestic care.
Reasons for No	Water Conservation	I prefer to save water by not having a constant supply. An intermittent supply helps reduce overall water usage and wastage.
	Sufficiency of Current Supply	Current water storage solutions like tinacos (water tanks) are sufficient for their needs, and they expressed satisfaction with an alternate day supply as it helps with water conservation.
	Cost and Financial Considerations	They were concerned about the additional cost of a constant water supply, believing that a limited supply helps reduce expenses.
	Environmental Concerns	They emphasized the importance of conserving water due to urban water scarcity and preferred to use water judiciously to protect the environment.

5.1.8 Conclusion to Question 6

Most respondents said they would prefer a daily direct water supply for convenience and quality of life, but a notable minority prioritized conservation, cost, and current storage sufficiency. Balancing these views is essential for an adequate water supply system.

5.2 Summary of Questionnaire 1

The following summary provides an overview of the responses from Questionnaire 1. Selected tables (Tables 5.1 to 5.5) with questions directly related to the research hypotheses are included in the main text, while tables with additional details and information can be found in Appendix K.

Community Concerns and Priorities

The results reflect the concerns of community members, with the most pressing issues being water supply, garbage management, stray dogs, and pollution. The community is focused on improving children's education and creating green areas while earning income. In the participants' responses, infrastructure improvements were also considered significant, though to a lesser extent. Building good relationships with neighbours was considered the least urgent priority. El Zangarro highly prioritizes environmental protection, as most participants consider it very important. This consensus shows the community's commitment to preserving their natural surroundings and indicates a supportive attitude toward initiatives aimed at *environmental* sustainability.

Regarding the water supply, most participants expressed frustration with the intermittent service. The lack of a daily water supply disrupts many aspects of life, from basic daily activities and hygiene to financial stress and environmental concerns. Ensuring a reliable water supply is crucial for improving quality of life and reducing the negative impacts of water shortages. Additionally, 82.95% of participants said they would like daily water in their homes, aligning with the 79.5% who reported dissatisfaction with the current inconsistent water supply.

Most respondents indicated that they would prefer a direct daily water supply for convenience and improved quality of life, but a minority prioritized conservation, cost concerns, and the sufficiency of their current water storage solutions. Striking a balance between these differing views is essential for developing an adequate water supply system. However, 55% of participants said they were unwilling to pay higher bills, revealing a divide in the community's willingness to invest financially in improved infrastructure. These results highlight the challenge of balancing the *benefits* of consistent water access with concerns about affordability.

Most participants (89.77%) said they had a water tank, showing that most households have adapted to the intermittent supply by storing water. A small percentage (10.23%) said they did not have a tank, relying entirely on a continuous water supply. Most households use elevated water tanks (tinacos) to cope with the intermittent supply, although there was a strong preference for daily direct water access, particularly among those without storage solutions.

Households have adjusted to the water supply challenges by using different tank sizes, most commonly medium-sized tanks (1100 litres), which help meet daily water needs by storing water. However, the data reveals an almost equal split between those with water cisterns (48.8%) and those without (51.12%), suggesting a potential area for improvement in the community's water storage infrastructure. While cisterns are another water storage method, they are costly and not as common as elevated tanks. The intermittent water supply has likely prompted the community to adopt storage systems as a mitigation strategy. Expanding cistern access could ensure a more reliable water supply for the community.

Bioenergy: Energy Generation and Fertilizer

Shifting from water to energy generation responses, 53.41% of respondents had heard that cooking gas could be generated from animal manure, while 46.59% had not. A smaller portion (37.50%) knew that energy could be produced from human excrement, 53.41% had not heard of it, and 9.09% were unsure.

Most respondents (58.14%) were open to using energy generated from human excrement, recognizing its *environmental* and *financial benefit*s. However, 41.86% had concerns, mainly regarding hygiene and health. While many acknowledged the *benefits* of using cooking gas from human waste, a significant portion of respondents still needed reassurance and education about the safety and advantages of bioenergy. On the other hand, most respondents (75.29%) said they were comfortable using energy from animal manure, appreciating its *environmental* and financial value, although 24.70% had concerns, primarily due to hygiene and a lack of knowledge. Providing more information on the safe and efficient use of this energy source could improve community acceptance.

Similarly, 59.3% of respondents expressed no concerns about using fertilizer from human excrement in their fields. Those concerned mentioned unknown factors, odour, health *risk*s from bacteria, and a general lack of information. In contrast, those without concerns either had a neutral stance or viewed it as a viable option. A large majority (80.7%) were also unconcerned about using fertilizer from animal manure, showing general acceptance. Among the 19.3% with concerns, the primary issues included health *risk*s, bacteria, odour, and curiosity about the production process.

However, health concerns were significantly higher regarding human excrement fertilizer. About 71.59% of respondents cited health *risk*s as their primary concern, followed by the smell (50%)

and general discomfort (38.64%). Only 18.18% of respondents had no concerns at all. Addressing these concerns, particularly around health and odour, could help increase acceptance of this practice.

For fertilizer from animal manure, 53.41% of respondents listed health as their primary concern, followed by odour (43.18%) and general discomfort (19.32%). Meanwhile, 36.36% had no concerns at all. A small portion worried about what others might think (3.41%), cost (11.36%), or other unspecified issues (7.95%). 61.36% of respondents said they were open to using cooking gas from animal manure, citing cleanliness and *environmental benefits*. However, 21.59% expressed concerns about hygiene and disgust, while 17.05% were unsure due to doubts about taste, smell, and health *risk*s. More education could address these uncertainties.

When asked about using gas for cooking produced from human excrement, 40.91% of respondents had no issue with it, while 35.23% expressed concerns. An additional 23.86% were unsure. The main concerns were health, odour, contamination, and general dislike, with some also mentioning uncertainty about the process, safety, and taste. Those who were unsure lacked knowledge of and familiarity with the topic.

Although 40.91% of respondents were open to using gas from human excrement, concerns about health, odour, and unfamiliarity with the process (35.23%) persisted. That 23.86% were unsure points to the need for more education to address uncertainties and increase acceptance.
Concerns about health and odour remained the most significant barriers to using gas from human waste. While 30.68% of respondents had no objections, addressing these issues could improve the overall acceptance of this energy source.

Most respondents (81.82%) were not familiar with the concept of bioenergy, while 18.18% had some understanding. Those people familiar with the concept associated it with natural resources, waste, and clean energy, citing production from corn, manure, and other organic materials.
Awareness of bioenergy is generally low, with only a small portion of respondents recognizing its generation potential from natural and waste resources. Increasing education on bioenergy could improve understanding and garner more support within the community. The term "bioenergy" may not have resonated with many respondents, leading to a lack of understanding.

Similarly, most respondents (86.36%) were unfamiliar with the concept of biodigesters, while 13.64% (12 participants) had some knowledge of them. Those familiar with biodigesters described them as containers for organic waste that produce biogas and biofuel, primarily from human and animal excrement. This result indicates that further education and outreach about biodigesters' *benefits* could be valuable for raising awareness and acceptance of these technologies within the community.

Solar Energy

Regarding solar energy, the community demonstrates a strong foundation of support, with over 94% of respondents expressing no concerns about using electricity generated from the sun. This outcome indicates broad acceptance, while concerns or uncertainties are minimal. However, efforts may still be needed to educate the remaining 6 % of the community to solidify support further.

In response to a question about specific concerns related to solar energy, most respondents (76.14%) reported no issues with using electricity produced by the sun. Among those expressing concerns, 11.36% cited health-related worries, and 10.23% were concerned about costs. A few participants mentioned discomfort (3.41%) or the smell (1.14%) of solar energy, while 7.95% had other unspecified concerns. Notably, no respondents expressed concerns about social perceptions, indicating that solar energy is widely accepted as a viable and beneficial energy source within the community.

Energy Usage and Blackouts

Electricity is primarily used for essential household activities such as lighting, operating televisions, and running washing machines. Additionally, appliances and electronic devices significantly contribute to overall electricity consumption. Respondents also indicated that energy is mainly used for work-related equipment, with 47.73% using refrigerators, ovens, or mills, followed by 37.50% using work tools. A smaller percentage (18.18%) said they used energy for pumps, while 25.00% cited other uses, including refrigerators, machinery, computers, lights, sewing machines, and washers. This usage is likely tied to the needs of small businesses in the area, such as stores requiring refrigerators, ovens for baking, and mills for grinding corn for tortillas.

Most respondents (68.18%) reported experiencing a blackout in their homes within the last three months, while 31.82% did not. Blackouts in the area are common, and the most cited reasons for power outages were power grid issues (45.45%) and weather conditions such as wind and heavy rains (42%). Fallen trees and other environmental factors also contribute to outages. Addressing these vulnerabilities and improving the reliability of the power infrastructure could help reduce the frequency and impact of blackouts, which also affect the community's water pump, leaving residents without water during outages. While most blackouts are resolved within 24 hours, restoration times vary, with some lasting longer. Addressing the causes of prolonged outages would improve overall reliability and minimize the disruptions caused by power cuts.

Regarding the water supply, 61.36% of participants reported being without direct tap water in the last three months, while 38.64% had not experienced any water outages. Interruptions in the water supply are frequent, with over 60% of respondents having recently faced a lack of water access. This result highlights the need for improvements in the water distribution system to ensure consistent access for the community.

Water outages often last for extended periods. Nearly half of the respondents (47.12%) reported being without water for several days, while 27.58% faced outages lasting only a few hours. A small portion (9.19%) were unsure of the duration, with others reporting times ranging from half a day (6.89%), one day (1.15%), to just minutes (1.15%). Addressing these prolonged outages is essential to improve the reliability of the water supply system.

For cooking, LP gas (butane) was the primary fuel for most households, with nearly 95% of respondents using it either always or very frequently. This result underscores the importance of ensuring the availability and affordability of LP gas in the community. However, firewood was also used by a portion of the population, with around one-third saying they used it occasionally and another quarter never using it. For some households, firewood remained a secondary fuel source, particularly for those who cannot afford LP gas. Some respondents mentioned using firewood as a secondary source for financial reasons, as they rely on it when they cannot afford gas.

Migration Intentions

Most community members (68.97%) said they were not considering emigration, and only a small percentage (16.09%) planned to move elsewhere. However, the uncertainty expressed by 14.94% of respondents indicates that emigration may become an option for some in the future, depending on changes in their circumstances.

In conclusion, the results from the first questionnaire strongly focus on environmental protection, water supply issues, and a cautious but open attitude towards bioenergy. Education and infrastructure improvements, particularly in water management and energy reliability, could address the community's concerns and help promote sustainable practices like bioenergy use.

5.3 Results from Questionnaire 2

This second questionnaire (Questionnaire 2) was administered after the participants received a presentation on solar panels and biodigesters, covering their uses, *benefits*, *risk*s, and costs.
This interpretation summarizes the most critical findings from the participants' responses, as shown in Tables 5.6 to 5.12.

5.3.1 Interpretation of Question 6

Question 6. How important do you consider that there are fewer flies in the environment (*environmental benefit*)?
Most respondents considered reducing flies in the environment highly important, with 70.59% rating it as very important and 20.00% as necessary. A smaller portion found this issue moderately important (3.53%) or of little importance (3.53%), while no respondents considered it insignificant (Table 5.6.)

Table 5.6. How important do you consider that there are fewer flies in the environment (*environmental benefit*)?

Answer choices	Responses (%) and Number of Participants
Very important	70.59%, 60
Important	20.00%, 17
Moderately important	3.53%, 3
Of little importance	3.53%, 3
Insignificant	0.00%, 0
I do not know	2.35%, 2

5.3.2 Conclusion to Question 6

The results indicate a strong community concern for reducing the number of flies in the environment, emphasizing the importance of environmental hygiene. Initiatives aimed at reducing the number of flies would likely be well-received and supported by the community.

5.3.3 Interpretation of Question 7

Question 7. How important do you think sewage cleanup is as an *environmental benefit* in your community?

Most respondents considered sewage cleanup a significant *environmental benefit*, with 72.94% rating it as very important and 18.82% as important. A smaller portion found it moderately important (4.71%), while no respondents considered it of little importance or insignificant (Table 5.7.).

Table 5.7. How important do you think sewage cleanup is as an *environmental benefit* in your community?

Answer choices	**Responses (%) and Number of Participants**
Very important	72.94%, 62
Important	18.82%,16
Moderately important	4.71%, 4
Of little importance	0.00%, 0
Insignificant	0.00%, 0
I do not know	3.53%, 3

5.3.4 Conclusion to Question 7

The results indicate a strong community emphasis on the importance of sewage cleanup, highlighting a significant concern for environmental hygiene. This result suggests that initiatives to improve sewage management would likely receive strong support from the community.

5.3.5 Interpretation of Question 8

Question 8. How important is it to reduce bad odours caused by animal manure in your community? Most respondents considered the reduction of unpleasant odours caused by animal manure important, with 62.35% rating it as very important and 24.71% as important. Only a few respondents found this issue moderately important (3.53%) or of little importance (2.35%), while no respondents considered it insignificant (Table 5.8.).

Table 5.8. How important do you think reducing bad odours caused by animal manure is in your community?

Answer choices	Responses (%) and Number of Participants
Very important	62.35%, 53
Important	24.71%, 21
Moderately important	3.53%, 3
Of little importance	2.35%, 2
Insignificant	0.00%, 0
I do not know	7.06%, 6

5.3.6 Conclusion to Question 8

The results indicate that reducing bad odours from animal manure is a significant concern for the community. Initiatives addressing these odours would likely receive strong support, reflecting the community's commitment to improving environmental quality and living conditions.

5.3.7 Interpretation of Question 24

Question 24. What would you be most concerned about using electrical energy produced by the sun?

Most respondents (83.53%) were not concerned about using the sun's electrical energy. A smaller portion was concerned about health (7.06%), personal discomfort (3.53%), and public opinion (1.18%). Additionally, 4.71% had other unspecified concerns (Table 5.9.).

Table 5.9. What would you be most concerned about using electrical energy produced by the sun?

Answer choices	Responses (%) and Number of Participants
Nothing	83.53%, 71
My health	7.06%, 6
I would not feel right	3.53%, 3
What people are saying	1.18%, 1
Other (explain)	4.71%, 4

5.3.8 Conclusion to Question 24

The results indicate strong community support for solar energy, with 83.53% of respondents expressing no concerns. Health, personal discomfort, and public opinion were minor concerns for some respondents. The high level of acceptance suggests that solar energy projects would likely be well-received and widely supported within the community.

5.3.9 Interpretation of Question 25

Question 25. Would your neighbours use fertilizer on their land produced from animal manure (biol)?

Most respondents (80.00%) believed their neighbours would use animal manure (biol) fertilizer on their land. A smaller portion (20.00%) provided reasons why they think their neighbours would use it (Table 5.10.).

Table 5.10. Do you think your neighbours would use fertilizer on their land produced from animal manure (biol)?

Answer choices	**Responses (%) and Number of Participants**
Yes	80.00%, 68
Why?	20.00%, 17

5.3.10 Conclusion to question 25:

The results indicate a strong belief within the community that neighbours would be willing to use fertilizer made from animal manure. This result suggests a high level of acceptance and potential for successfully adopting biol as a fertilizer within the community. Addressing any specific reasons and concerns could further enhance this acceptance.

5.3.11 Interpretation of Question 27

Question 27. Would you buy cooking gas obtained from animal manure?
Most respondents (82.35%) said they were willing to buy cooking gas from animal manure. A smaller portion (17.65%) provided reasons why they would make this choice (Table 5.11.).

Table 5.11. Would you buy cooking gas obtained from animal manure?

Answer choices	**Responses (%) and Number of Participants**
Yes	82.35%, 70
Why?	17.65%, 15

5.3.12 Conclusion to Question 27

The results indicate strong support for purchasing cooking gas derived from animal manure, with 82.35% of respondents expressing willingness. This result suggests a high acceptance and openness to alternative, sustainable energy sources within the community. Addressing any specific reasons and concerns mentioned by the smaller portion of respondents could further enhance this acceptance and encourage wider adoption.

5.3.13 Interpretation of Question 31

Question 31. Which of the following do you consider most important in investing the money raised from the project?

Respondents prioritized investing the money raised from the project in the following areas: a community garden (30.59%), school maintenance and restoration (28.24%), and improvement of streets and roads (24.71%). Fewer respondents prioritized free internet access (9.41%), additional income for each family (1.18%), and other unspecified areas (5.88%) (Table 5.12.).

Table 5.12. Which of the following do you consider most important in investing the money raised from the project?

Answer choices	**Responses (%) and Number of Participants**
Community garden	30.59%, 26
Free Internet access in the community	9.41%, 8
School maintenance and restoration	28.24%, 24
Improvement of streets and roads	24.71%, 21
As additional income for each family	1.18%, 1
Other (explain)	5.88%, 5

The results indicate that the community prioritizes investing in communal and infrastructure projects, with the top preferences being a community garden, school maintenance and restoration, and street and road improvements. The respondents saw these areas as most beneficial for the community's development and well-being, suggesting that funds should be allocated accordingly to address these priorities.

5.4 Summary of Questionnaire 2

The second questionnaire, administered after a presentation on biodigesters and solar panels, provides an insightful overview of the community's updated perceptions and willingness to adopt sustainable technologies. The results reflect overwhelming support for these renewable energy initiatives, with most respondents showing strong interest in their *benefits*. The following summary provides an overview of the responses from Questionnaire 2. Selected tables are included in the main text (Table 5.6 to 5.12), while additional detail tables can be found in Appendix K.

A key finding is that 91.76% of the community members believe that biodigesters would help their community by providing renewable energy, managing waste, and enhancing sustainability. However, some concerns about implementation persist. The most significant issues raised include the collection of animal manure (15.38%) and its availability (8.97%), as well as associated costs (7.69%). Despite these concerns, nearly half of the respondents (46.15%) foresee no significant challenges in adopting biodigesters, highlighting optimism and potential support for the project.

Regarding the perceived *benefits*, respondents emphasized biodigesters' financial savings (44.87%) and *environmental* advantages (29.49%). Gas (15.38%) and fertilizer (10.26%) production were also important, though secondary, *benefits*. This focus on financial and ecological impacts suggests the community is motivated to adopt the technology for its cost-effective and environmentally friendly potential.

Solar energy also garnered widespread approval, with 96.47% of respondents believing solar panels would benefit the community. financial savings (43.90%) and *environmental benefits* (21.95%) were identified as the most significant advantages, along with the potential for energy independence (12.20%) and *community benefits* (13.41%). The general positive perception of solar energy reflects the community's openness to transitioning to renewable energy sources.

Responses on other *environmental benefits* further support the environmental aspects of the projects. For example, reducing flies (90.59%) and cleaning up sewage (91.76%) were considered very important or important by respondents, reflecting concern for improving local environmental conditions. Furthermore, addressing the bad odours caused by animal manure was also prioritized, with 87.06% considering it very important or important.

Financial benefits also play a critical role in the community's support for renewable energy initiatives. 95.29% of respondents viewed electricity bill savings as highly important, while

74.12% emphasized reducing gas costs. These findings demonstrate that the community values the financial relief that renewable energy projects can provide, which is a key motivating factor for their support. When asked how the financial gains from the project should be invested, some respondents (43.53%) preferred receiving discounts on their electricity bills. However, a significant portion (29.41%) believed the funds should be reinvested in community projects, with others suggesting a community savings fund (21.18%). These responses balance individual *financial benefits* and a broader communal focus on long-term development.

Respondents also expressed strong interest in participating in the projects, with 78.82% indicating a willingness to get involved. Additionally, 85.88% were open to working with others in the community to ensure the success of the projects. This data demonstrates high community engagement and collective support for renewable energy initiatives. However, opinions varied regarding the perceived ease of participation. While 48.41% felt it would be relatively easy for community members to join the project, others anticipated moderate difficulty (21.18%) or challenges (11.76%). Addressing these concerns through clear communication and support could facilitate broader involvement.

The maintenance of the biodigester was seen as a community responsibility, with 49.41% preferring that a community employee handle it and 30.59% supporting the idea of a community volunteer. This strong preference for local involvement underscores the community's desire for ownership and responsibility over the project's long-term sustainability. 80 % of the respondents were willing to volunteer for one to four hours per week, and 20% were not willing to volunteer at all. Incentives may be necessary to ensure adequate volunteer support and encourage broader participation.

Regarding managing the savings generated from maintenance, 61.18% of respondents preferred investing these funds in community infrastructure, while 34.12% supported distributing the savings as additional income for families. This outcome indicates a focus on communal improvements, although there is also significant interest in direct *financial benefit*s.

Demographically, the survey revealed that most respondents were female (62.35%), and the largest age group was teenagers aged 14-17 (24.71%). These findings suggest broad representation from different community segments, with women and younger individuals playing a pivotal role in shaping opinions on renewable energy initiatives.

Educationally, most respondents had completed high school (36.47%) or middle school (28.24%), while income levels varied widely. The largest income group earned between 500-1000 MXN per week (41.18%), reflecting a financially diverse community with varying financial conditions.

Overall, the community strongly supports renewable energy projects, with a clear focus on *environmental* and *financial benefits.* However, addressing logistical concerns, such as manure collection and maintenance, and educating the community on health and hygiene related to biodigester and solar panel usage will be essential for successful implementation. The community's willingness to participate and collaborate in these projects reflects a high potential for success if concerns are addressed and clear support structures are in place.

5.5 Summary of Questionnaire 3

Questionnaire 3 presents a detailed overview of the responses from local ranchers on their livestock management practices and willingness to participate in the community's biodigester project. The findings highlight the availability of livestock manure for the biodigester and identify key considerations for ensuring the project's success. The following summary provides an overview of the responses from Questionnaire 3. Detailed tables can be found in Appendix K.

Most respondents (75%) said they used their livestock manure as fertilizer, indicating its value in local agricultural practices. This result suggests that manure is already a resource that ranchers recognize as beneficial, though none of the respondents reported selling it or leaving it for others to collect. A smaller portion (25%) mentioned other uses for the manure, reflecting some diversity in its application.

The data shows that ewes (33.91%) and goats (28.10%) are the most common livestock among the respondents, followed by sheep (14.53% and cows (10.85%). Mares and mules represent less than 1% each. This distribution underscores the community's focus on small ruminants, which are well-suited to the local environment. It also points to the types of manure most available for the biodigester project, primarily from ewes, goats, sheep, and cows.

Grazing practices among ranchers vary significantly. While some do not take their livestock out to graze due to a lack of pasture, others graze their animals daily or several times a week. This variation suggests that pasture availability is uneven across the community, which could affect how much manure ranchers can contribute to the biodigester. Regular grazing practices likely correlate with a steady supply of manure, while those who do not graze their livestock may contribute less.

There was overwhelming support for the biodigester project, with 91.67% of ranchers expressing their willingness to contribute livestock manure. This strong backing indicates that the community sees the project's potential *benefits*, such as renewable energy production and improved waste management. The high level of interest suggests that the project will have a steady supply of manure to operate effectively.

Most ranchers (58.33%) indicated they could contribute manure once a week, 25% could do so daily, and 16.67% could contribute three to five days a week. This consistency in manure availability is crucial for the biodigester's operations, as it ensures a regular input of organic material to sustain the energy production process.

The total potential manure contribution from the respondents totals approximately 875 kilograms, with individual contributions ranging from 0 to 300 kg. This significant supply of manure demonstrates that the community can provide ample organic material to sustain the biodigester's operations. However, the wide range of contributions reflects the diversity in livestock numbers and management practices among ranchers.

Half of the respondents (50%) said they could transport the manure themselves, while 33.33% mentioned their ability to transport it depends on the distance. Only 16.67% required the manure to be collected. This result suggests that while many ranchers are willing and able to transport manure to the biodigester, the project may still need to offer logistical support to ensure that all contributing ranchers can participate effectively.

Most ranchers (91.67%) said they were unwilling to pay for frequent cleaning of their animal pens. This reluctance suggests that financial incentives or alternative arrangements may be necessary to encourage regular pen cleaning, which is essential for maintaining a steady supply of manure for the biodigester. Additionally, none of the respondents (100%) expressed willingness to pay for pen cleaning every third day, reinforcing the need for external support or creative solutions to manage this aspect of the project.

Most ranchers (66.67%) said they would prefer to receive fertilizer in exchange for their manure contributions, while a smaller group (25%) preferred monetary compensation. Fertilizer was seen as a valuable *benefit*, suggesting that offering it in return for manure contributions could serve as a strong incentive and ensure the project's success.

When asked about the problems in their community that the biodigester project could help address, ranchers identified the lack of water (50%) and garbage management (33.33%) as the most pressing issues. This feedback suggests that the income generated by the biodigester project could be directed toward improving water access and waste management, both of which are critical concerns for the community.

Most respondents (75%) were male, indicating that men are primarily involved in livestock and manure management. However, the participation of female ranchers (25%) shows that women also play a role in these activities. The largest groups of respondents were in the 35-39 and 55-59 age brackets, suggesting that mid-career and older ranchers are the most involved in livestock management and could be key stakeholders in the biodigester project.

Most ranchers have completed either primary or secondary school, indicating a basic level of formal education. This result suggests that any training or educational materials related to the biodigester project should be accessible and practical to ensure strong community engagement. Regarding occupation, most respondents are either farmers or homemakers, which aligns well with the goals of the biodigester project, as both groups would directly *benefit* from manure-to-energy conversion.

In conclusion, the findings from Questionnaire 3 indicate strong community support for the biodigester project, with most ranchers willing to contribute livestock manure. The steady supply of manure and the ranchers' interest in receiving fertilizer as compensation suit the project's success well. However, logistical support, especially with manure transportation and pen cleaning, will be essential to ensure consistent participation. Addressing critical community issues such as water access and garbage management through the project's income could further enhance community support and involvement.

This detailed understanding of the ranchers' livestock practices, manure management, and attitudes toward the biodigester project provides a solid foundation for planning and implementing the project while accounting for the community's needs and capacities.

5.6 Community Valuation of ***Benefits***

According to the responses from Questionnaire 1, the residents of El Zangarro place a high value on *private benefits*, especially water availability. They recognize that reliable access to water improves their quality of life, contributes to better hygiene, and positively impacts their health, reducing the costs of purchasing water from external sources. *Private benefits*, particularly those related to essential needs like health and sanitation, are considered fundamental for individual and family well-being. At the same time, the community places high importance on *community benefits*. Issues such as garbage management, stray dogs, and social problems were identified as critical concerns affecting collective well-being. These problems are closely related to environmental concerns, as garbage management and stray dogs are part of the effort to maintain a clean and healthy environment. Environmental concerns were ranked second in importance, with the community showing clear awareness of pollution and the need to preserve green spaces. This result underscores their recognition of *environmental benefits*, particularly environmental protection and sustainability, complementing private and community needs. Conversely, issues like lack of money were ranked as less critical, indicating that financial concerns are less urgent than more immediate matters related to community welfare and environmental issues.

In a follow-up question asking participants to rank their priorities, most identified *community benefits* as the most important, often linked to *private benefits* like improving children's education. *Environmental benefits* (enhancing green areas) were ranked second, followed by *financial benefits* like earning money. However, while financial gains are substantial, they are not considered the top priority, as improvements to infrastructure and other communal projects tend to take precedence.

A notable observation from the survey is that most respondents considered protecting the environment and nature highly important, with none viewing it as a minor concern. This result demonstrates the community's strong commitment to sustainability and environmental preservation.

In Questionnaire 2, responses also reflect this prioritization. When asked multiple-choice questions about where they would prefer to allocate funds generated by potential projects, respondents favoured environmental projects, such as parks and gardens, followed by *community benefits* related to infrastructure and education and *private benefits,* such as food, clothing, and healthcare. In another multiple-choice question, participants were asked again how they would allocate the money generated by these projects. They favoured *private benefits*, followed by community projects and the creation of a community savings fund. Another open-ended question, in contrast, showed *community benefits* (education and infrastructure) as the first choice, *environmental benefits* (environmental projects) as second, and *private benefits* (health and family) as last for allocating project-generated funds. In another question related to financial savings due to maintenance, they decided that *private benefits* come first and *community benefits* (infrastructure) second.

In contrast, when asked directly about the *benefits* that projects like biodigesters and solar panels would bring to their community, the first answer was financial savings, followed by *environmental benefits*. The third most frequently mentioned *benefit* of the biodigester was gas production *(private benefit*). In fourth place, respondents highlighted *community benefits* for the biodigester and *private benefits* for the solar panels.

Community Valuation Conclusion

The results of the first questionnaire indicate that the community of El Zangarro places high importance on *private* and *community benefits,* with a particular focus on *environmental benefits* related to environmental preservation. However, when presented with hypothetical scenarios where new projects might be introduced, the emphasis shifts toward financial savings as the top priority, followed by *environmental,* community, and *private benefits* (in that order).

The following section details Research Questions 1 and 2, providing a direct and concise response.

5.7 Answer to Research Question 1

After analyzing the questionnaire answers, Research Question 1 was answered (Table 5.13).

Table 5.13. Research Question 1

1)What is the notion of sustainability in the community of El Zangarro?	
Hypothesis	The community perceives sustainability as important.
Method	Responses from Questionnaire 1 (Q3, Q6) and Questionnaire 2 (Q6a, Q6b, Q6c, Q31)
Test	Most answers (>50%) show that sustainability is important to respondents.

-Questionnaire 1, Q3: All respondents indicated that protecting the environment and nature is either very important or important.

-Questionnaire 1, Q6: 82.95% of respondents strongly desire direct water access daily, linking it to sustainable water management practices.

-Questionnaire 2, Q6a-Q6c: 90.59% of respondents rated the reduction of flies as very important or important, while 3.53% considered this matter of little importance.

-Questionnaire 2, Q31: Most respondents prioritized investments in sustainability, with 30.59% supporting initiatives like community gardens and infrastructure improvements.

5.8 The Conclusion to Research Question 1

The results confirm that the community of El Zangarro values sustainability highly. The majority of respondents view environmental protection and nature preservation as crucial, with 100% of participants expressing this in Questionnaire 1 (Q3). Furthermore, 82.95% of respondents strongly desired daily water access, suggesting a connection to sustainable water management practices (Q6). Similarly, 90 % of respondents rated the reduction of flies, an environmental concern, as very important or important (Questionnaire 2, Q6a-Q6c).

However, only 30.59% of respondents prioritized sustainability-oriented initiatives, such as community gardens, as the most important use of funds raised from the project (Q31). Other pressing community issues, such as school maintenance and the restoration and improvement of streets and roads, were also identified as needing attention. These findings suggest that while sustainability is important to the community, broader community needs must also be addressed. The hypothesis is supported, as more than 50% of the respondents showed that sustainability is important.

5.9 Answer to Research Question 2

After analyzing the answers from the questionnaires, the following Research Question 2 was answered (Table 5.14.):

Table 5.14. Research Question 2

2) How does the community notion of sustainability fit with community priorities?	
Hypothesis	Respondents connect sustainability issues to community priorities.
Method	Responses from Questionnaire 1 (Q1, Q2) and Questionnaire 2 (Q7a, Q7b, Q8a, Q8b, Q24, Q25, Q27).
Test	Most respondents (>50%) include sustainability issues among community problems and agree with the importance of the *financial* and *social benefits* of the project alternatives.

Questionnaire 1, Q1- Almost 60% of the critical problems mentioned were related to sustainability issues. Water supply, garbage management, stray dogs, pollution and green spaces were mentioned in order of importance.

- Questionnaire 1, Q2- The primary focus for the community is improving children's education (40%), followed by enhancing green areas in the community (36%).
- Questionnaire 2, Q7a-Q7b: 92% of respondents rated sewage cleanup as very important or important.
- Questionnaire 2, Q8a-Q8b: 87.06% considered odour reduction crucial, indicating solid connections between these environmental issues and the community's broader sustainability priorities.
- Questionnaire 2, Q24:83.53% of the respondents were not concerned about using sun's as electricity.

- Questionnaire 2, Q25:80% of the respondents considered that their neighbours would not have a problem using fertilizer from animal manure.
- Questionnaire 2, Q27: 82.35% of the respondents are willing to buy gas produced from animal manure.

5.10 The Conclusion to Research Question 2

The results demonstrate a strong connection between the community's notion of sustainability and their broader priorities. Nearly 60% of the critical problems identified by respondents in Questionnaire 1 (Q1) are related to sustainability issues, such as water supply, garbage management, stray dogs, pollution, and green spaces. Additionally, the community places high importance on addressing these environmental concerns, with more than 90% rating sewage cleanup as very important or important (Questionnaire 2, Q7a-Q7b) and 87.06% considering odour reduction crucial (Questionnaire 2, Q8a-Q8b). However, there is also a notable focus on non-sustainability-related priorities, such as improving children's education, which was ranked as the top priority by 40% of respondents in Questionnaire 1 (Q2), followed by enhancing green areas (36%). This shows that while sustainability is an important aspect of the community's priorities, it is balanced with social and educational concerns. Moreover, respondents show openness to sustainability initiatives, as 80% believe their neighbours would not have issues using fertilizer from animal manure (Q25), and 82.35% are willing to purchase gas from animal manure (Q27). Despite this, 83.53% expressed no concerns about using solar power for electricity (Q24), indicating that the community is receptive to integrating sustainable solutions into their daily lives.

The hypothesis is supported, as more than 50% of the respondents include sustainability issues among the community's problems and demonstrate a positive attitude towards the *financial* and *social benefits* of the project alternatives. These results align with the hypothesis, showing that the community connects sustainability issues to their broader priorities.

5.11 Implications for Future Actions

Based on the information obtained from the questionnaires, these are recommendations for future action to address the community's priorities and concerns.

1) Enhance Environmental Education: Given the community's concern for environmental protection, initiatives that educate and engage the community on sustainable practices should be expanded.

2) Focus on Water Management: The community's emphasis on clean water access indicates a need for improved water management strategies, including investments in sustainable water infrastructure and conservation practices.

3) Take an Integrated Development Approach: Any sustainability projects should be holistic, aligning environmental, educational, and financial needs with the community's broader priorities.

4) Prioritize Renewable Energy Projects: The overwhelming support for solar panels and biodigesters suggests that renewable energy projects should be prioritized in future community planning, focusing on expanding access to and education about these technologies.

5) Improve Environmental Cleanliness: Continued investment in environmental cleanliness (waste management and reducing agricultural odours) should be a key focus area for improving living conditions and meeting community expectations.

6) Prioritize Sustainability-Focused Investments: Future funding and development efforts should prioritize sustainability-focused investments, particularly those that offer immediate, tangible *benefits* to the community, such as community gardens and infrastructure improvements.

7) Address Logistical Concerns: To ensure the success of the biodigester project, logistical challenges (manure transportation) and maintenance need to be addressed through local community-based solutions.

8) Provide Tangible Benefits: It is important to ensure that participants receive clear, tangible *benefits*, such as fertilizer from the biodigester project, to maintain high levels of participation in sustainability projects.

9) Encourage Local Ownership: Given the community’s preference for local management, future projects should aim to build local capacity and ownership to enhance the sustainability and longevity of these initiatives.

5.12 Discrete Choice Experiment (DCE)

This section presents the findings of the discrete choice experiment (DCE) using a mixed logit model. The results show how community members perceive and evaluate the *benefits* of alternative energy projects. The analysis aims to answer research questions 3 and 4, shown in Table 5.15.

Table 5.15. Research Questions 3 and 4.

3) How do community members perceive and evaluate the *benefits* of alternative energy projects?	
4) What are the trade-offs involved in the alternative project scenarios and community members' preferences for these scenarios?	
Hypothesis 3	Respondents are willing to accept the trade-offs of sustainability.
Method	Respondents are willing to pay for project attributes that improve living conditions (project alternatives 2, 3, 4) and sustainability (project alternatives 3 and 4).

Figure 5.2 shows the mixed logit choice model results. It indicates the coefficients, standard errors, z-values, and significance for each attribute and level considered in the analysis. Ninety-eight participants were interviewed for this DCE, providing insights into the community members' preferences and priorities.

```
Mixed logit choice model                          Number of obs       =      6,268
                                                  Number of cases     =      1,567
Panel variable: id                                Number of panels    =         98

Time variable: t                                  Cases per panel: min =        15
                                                                   avg =      16.0
                                                                   max =        16

Alternatives variable: Alt                        Alts per case:   min =         4
                                                                   avg =       4.0
                                                                   max =         4

Integration points:             0                     Wald chi2(10)   =     189.33
Log pseudolikelihood = -1700.5279                     Prob > chi2     =     0.0000

                                             (Std. err. adjusted for clustering on id)
--------------------------------------------------------------------------------------
                 |               Robust
          chosen | Coefficient  std. err.      z    P>|z|     [95% conf. interval]
-----------------+--------------------------------------------------------------------
Alt              |
  privatebenefit |
               2 |  -.1866234   .0592432    -3.15   0.002      -.302738   -.0705089
               4 |          0  (omitted)
                 |
communitybenefit |
               2 |  -.0044326   .0867664    -0.05   0.959     -.1744917    .1656264
               3 |     .00871    .099414     0.09   0.930     -.1861378    .2035579
               4 |          0  (omitted)
                 |
   globalbenefit |
               3 |   .5625186   .0855144     6.58   0.000      .3949134    .7301238
               4 |   .7183316   .1002195     7.17   0.000       .521905    .9147581
                 |
            risk |
               2 |   .1035488   .0721274     1.44   0.151     -.0378184    .2449159
               4 |  -.4881705   .0952898    -5.12   0.000     -.6749351   -.3014059
                 |
           cost2 |  -.0042348   .0007029    -6.03   0.000     -.0056124   -.0028572
                 |
 economicbenefit |
               3 |   .7446215   .0997566     7.46   0.000      .5491021    .9401408
               4 |   .9619012   .1133425     8.49   0.000      .7397541    1.184048
-----------------+--------------------------------------------------------------------
1                |  (base alternative)
-----------------+--------------------------------------------------------------------
2                |
           _cons |   .2078245    .094806     2.19   0.028      .0220081    .3936409
-----------------+--------------------------------------------------------------------
3                |
           _cons |   .1195555   .0934157     1.28   0.201      -.063536     .302647
-----------------+--------------------------------------------------------------------
4                |
           _cons |  -1.260718   .3485347    -3.62   0.000     -1.943833   -.5776021
--------------------------------------------------------------------------------------
```

Figure 5.2. Output of the Mixed Logit Choice Model Analysis

5.13 Perception and Evaluation of *Benefits* Results

According to Figure 5.2, the DCE results reveal that participants highly value *financial* and *environmental benefits*. Specifically, the levels associated with the highest *environmental benefits* (Levels 3 and 4) received the most positive evaluations, indicating that participants highly regard improvements to *environmental* sustainability. Moreover, *financial benefit*s (Levels 3 and 4) were also highly valued, suggesting that community members appreciate projects that promise to enhance their financial well-being. These results answer the first research question, which focuses on understanding how community members perceive and evaluate the *benefits* associated with alternative energy projects.

5.14 Trade-offs in Alternative Project Scenarios

Research question 4, on the trade-offs involved in project scenarios, reveals that participants are willing to accept some trade-offs for projects that align with their priorities. The mixed logit analysis showed the following:

- *Environmental benefits* significantly increase the likelihood of project selection, as community members are highly motivated by *environmental* sustainability.
- *Financial benefit*s are also a key driver in decision-making, with participants preferring projects that promise substantial financial gains.
- *Private benefits* (mainly medium levels) and *community benefits* are less influential, suggesting that while important, they are not decisive factors in selecting projects
- *Risk* aversion is evident, particularly with high-*risk* scenarios, which significantly reduce the likelihood of a project being chosen.
- Cost plays a crucial role, with higher costs preventing community support, reflecting typical financial behaviour.

5.15 Key Findings from the Mixed Logit Choice Model

Table 5.16 presents the key findings from the Mixed Logit Choice Model on the significant *benefits* for the community.

Table 5.16. Key Findings from the Mixed Logit Choice Model

Attribute	**Level**	**Coefficient**	**Significance (p-value)**	**Interpretation**
Private benefits	Level 2	-0.1866234	0.002	A medium level of *private benefits* decreases the likelihood of selecting the scenario compared to the baseline (Level 1 or status quo).
Community Benefits	Level 2	-0.0044326	0.959	Medium *community benefits* have a negligible and statistically insignificant effect on choice probability.
Community Benefits	Level 3	0.00871	0.930	High *community benefits* also have a negligible and statistically insignificant effect on choice probability.
Environmental benefits	Level 3	0.5625186	< 0.001	High *environmental benefits* significantly increase the likelihood of scenario selection, indicating a strong preference for environmental sustainability.
Environmental benefits	Level 4	0.7183316	< 0.001	Very high *environmental benefits* further increase the likelihood of selection, highlighting the importance of environmental sustainability in decision-making.
Risk	Level 2	0.1035488	0.151	Medium *risk* does not significantly affect the choice probability.
Risk	Level 4	-0.4881705	< 0.001	The high *risk* significantly decreases the likelihood of selecting the scenario, suggesting participants are *risk*-averse regarding alternative energy projects.
Cost	-	-0.0042348	< 0.001	Higher costs reduce the likelihood of scenario selection, aligning with typical financial behaviour where increased costs deter choices.
Financial benefits	Level 3	0.7446215	< 0.001	High *financial benefits* significantly increase the likelihood of selection, showing a high value placed on financial improvements.
Financial benefits	Level 4	0.9619012	< 0.001	Very high *financial benefits* increase the likelihood of selection, indicating a strong preference for scenarios with substantial *financial benefits.*

5.16 Summary of Results by Attribute

The Mixed Logit Choice Model results reveal several key trade-offs participants make when evaluating different project scenarios. The findings show that participants place varying levels of importance on each attribute, with clear preferences emerging for some and less influence observed for others.

Private Benefits

The level 2 (moderate *private benefits*) coefficient is negative and significant (-0.1866, p = 0.002), indicating that participants are less likely to choose scenarios with medium *private benefits*. This result suggests that participants do not find moderate levels of *private benefits* particularly appealing and are willing to trade them off in favour of other, more appealing project characteristics.

Community Benefits

For *community benefits*, the coefficients for Levels 2 and 3 are close to zero (-0.0044 and 0.0087), with high p-values (0.959 and 0.930). This result indicates that *community benefits*, regardless of the level, do not significantly influence participants' choices. As such, *community benefits* are not a decisive factor in the decision-making process, and participants seem indifferent to this attribute.

Environmental Benefits

In contrast, *environmental benefits* strongly positively and significantly influence participants' decisions. The coefficients for Levels 3 and 4 are 0.5625 and 0.7183, with p-values of 0.000, highlighting that participants prefer scenarios with high or very high *environmental benefits*. This result indicates that *environmental* sustainability is a critical factor in the decision-making process, with participants willing to accept trade-offs (such as higher costs) in favour of contributing to *environmental benefits*.

Risk

Level 2 (low *risk*) has a positive but not significant coefficient (0.1035, p = 0.151), suggesting that low *risk* does not significantly impact the choice of scenarios. Participants seem somewhat indifferent to low levels of *risk*, as it does not strongly sway their decisions. Level 4 (high *risk*), on the other hand, shows a negative and significant coefficient (-0.4882, p = 0.000), indicating that high levels of *risk* significantly reduce the likelihood of a scenario being chosen. This reveals participants' strong aversion to high-*risk* scenarios, suggesting they prioritize avoiding *risk* when considering different project alternatives.

Cost

The effect of cost is also significant, with a negative coefficient of -0.0042 ($p = 0.000$). This result indicates that the likelihood of a chosen scenario decreases as costs increase. Cost is a crucial factor for participants, and affordability is an important consideration in their decision-making process.

Financial Benefits

Finally, participants highly value *financial benefit*s, with levels 3 and 4 coefficients being 0.7446 and 0.9619, respectively (p-values of 0.000). This result shows that high and very high *financial benefit*s strongly influence participants' choices, suggesting that *financial* improvements are a key driver in their decision-making.

5.17 Overall Summary

Participants are most motivated by *environmental* and *financial benefits* and prefer scenarios that improve *environmental* sustainability and offer significant *financial* advantages. Cost and *risk* also play critical roles, with participants demonstrating a solid dislike of high *risk*s. On the other hand, *private* and *community benefits* are less influential, with participants willing to sacrifice moderate levels of *private* and *community benefits*.

5.18 Willingness to Pay (WTP) Analysis

Including cost as an attribute in the mixed logit model allows the estimation of the willingness to pay (WTP) for each attribute. (e.g., *environmental benefits*, *financial benefits*). WTP represents the amount of money respondents are willing to sacrifice to obtain a higher level of a given attribute.

5.18.1 Calculating WTP

WTP for a specific attribute is calculated as the ratio of its coefficient to the coefficient of the cost variable. This ratio represents the trade-off between the attribute and the cost that respondents are willing to make. Given the cost coefficient ($\beta cost = -0.0042348$), we can calculate the WTP for each significant attribute as follows:

To calculate the Willingness to Pay (WTP) for each attribute, we use the following formula:

$$WTP = \beta\_attribute / \beta\_cost \quad (3)$$

Where:
β_attribute: coefficient for the specific attribute and level.
β_cost: coefficient for cost (-0.0042348).

In Table 5.17, the WTP results of each level of attributes are described.

Table 5.17. Willingness to Pay (MXN)

Attribute	Level	WTP (MXN)
Environmental benefits	Level 1	-0.00
Environmental benefits	Level 2	-0.00
Environmental benefits	Level 3	-132.83
Environmental benefits	Level 4	-169.63
Financial benefits	Level 1	-0.00
Financial benefits	Level 2	-0.00
Financial benefits	Level 3	-175.83
Financial benefits	Level 4	-227.14
Risk	Level 1	-0.00
Risk	Level 2	-24.45
Risk	Level 3	-0.00
Risk	Level 4	115.28
Private benefits	Level 1	-0.00
Private benefits	Level 2	44.07
Private benefits	Level 3	-0.00
Community benefits	Level 1	-0.00
Community benefits	Level 2	1.05
Community benefits	Level 3	-2.06
Community benefits	Level 4	-0.00

5.18.2 Summary of WTP Analysis

The Willingness to Pay (WTP) analysis provides insights into the monetary value that respondents assign to various attributes of the alternative energy projects. Table 5.18 summarizes the WTP for each significant attribute:

Table 5.18. Summary of WTP for Significant Attributes

Benefit Type	**Level**	**Willingness to Pay (MXN)**	**Interpretation**
Environmental benefits	Level 3	132.82 MXN	Respondents are willing to pay for high *environmental benefits*.
	Level 4	169.61 MXN	Respondents are willing to pay more for the highest *environmental benefits*.
Financial Benefits	Level 3	175.84 MXN	Respondents value high *financial benefits* and are willing to pay accordingly.
	Level 4	227.18 MXN	Respondents place a high value on the highest *financial benefits.*
Risk Reduction	Level 4	115.29 MXN	Respondents strongly prefer *risk* reduction in energy projects.
Private benefits	Level 2	44.07 MXN	Respondents are moderately willing to pay for *private benefits*, indicating lower priority.
Community Benefits	Levels 2 & 3	Not statistically significant	*Community benefits* are not a substantial factor for respondents.

The WTP analysis reveals the monetary value community members assign to different project attributes. Participants are willing to pay significantly more for projects offering high *environmental* and *financial benefits*, while they are also willing to pay to avoid high-*risk* scenarios. For example, participants are willing to pay up to 227.18 MXN for very high *financial benefit*s and 169.61 MXN for high *environmental benefits*, highlighting their priorities. In contrast, lower WTP values are associated with *private* and *community benefits*, emphasizing the community's focus on *environmental* and *financial* factors.

Based on the provided Discrete Choice Experiment (DCE) analysis and the findings from the mixed logit choice model, here are the answers to the research questions:

5.19 Answer to Research Question 3

How do community members perceive and evaluate the *benefits* of alternative energy projects? Community members perceive and evaluate the *benefits* of alternative energy projects through a strong emphasis on *financial* and *environmental benefits*. The DCE results show that the participants place a high value on project attributes that contribute to Environmental sustainability and enhance their *financial* well-being:

- *Environmental benefits*: High levels of *environmental benefits* (Levels 3 and 4) were particularly valued by the community, with coefficients of 0.5625186 and 0.7183316, respectively, and both being statistically significant ($p < 0.001$). This outcome indicates that the community members highly regard improvements that contribute to Environmental sustainability and are willing to choose projects that deliver these *benefits*.

- *Financial benefits*: Similarly, high levels of *financial benefits* (Levels 3 and 4) were also highly valued, with coefficients of 0.7446215 and 0.9619012, respectively, both with high significance ($p < 0.001$). This result suggests that community members appreciate projects that promise to enhance their financial situation, aligning with their preferences for projects that improve their financial well-being.

The Willingness to Pay (WTP) analysis further supports these findings, showing that respondents are willing to pay significant amounts for projects with high Environmental and *financial benefits.* For instance, respondents are willing to pay approximately 169.61 MXN for high *environmental benefits* (Level 4) and 227.18 MXN for high *financial benefits* (Level 4), highlighting the importance of these attributes.

The community's evaluation of alternative energy projects reflects a balanced approach, with high priorities for *environmental* sustainability and financial improvement.

5.20 Answer to Research Question 4

What are the trade-offs involved in the alternative project scenarios and community members' preferences for these scenarios?

The trade-offs that community members are willing to make in alternative project scenarios primarily involve balancing *benefits* with *risk*s and costs:

- *Risk*: The analysis reveals that community members are *risk*-averse, particularly when it comes to high levels of *risk* (Level 4), which significantly reduces the likelihood of a scenario being chosen (coefficient: -0.4881705, $p < 0.001$). This result indicates that while respondents are willing to accept some level of *risk*, they strongly prefer scenarios where the *risk*s are minimized.
- Cost: As expected, higher costs reduce the likelihood of a scenario being selected (coefficient: -

0.0042348, p < 0.001). This outcome aligns with typical financial behaviour, where participants are less likely to choose scenarios that involve higher financial burdens, indicating a trade-off between the desired *benefits* and the willingness to incur additional costs.

- *Private* and *community benefits*: The analysis shows that medium levels of *private benefits* (Level 2) decrease the likelihood of a scenario being chosen, and *community benefits* do not significantly influence decision-making. This result suggests that while respondents appreciate some level of personal and *community benefits*, these are not the primary drivers of their decision-making compared to *environmental* and *financial benefits*.

5.21 Summary of Results

The DCE results provide explicit answers to the research questions:
1. Perception and Evaluation of Benefits: Community members prioritize Environmental sustainability and *financial benefit*s. The strong positive coefficients for high levels of these *benefits* reflect their importance in decision-making.

2. Trade-offs in Project Scenarios: Community members are willing to trade off higher costs and some personal *benefits* in favour of projects that contribute to *environmental* sustainability and *financial* well-being. However, they are *risk*-averse, preferring projects that minimize *risk*s.

5.22 Hypothesis Testing

Hypothesis 1: Respondents are willing to accept the trade-offs of sustainability.
This hypothesis is supported. The analysis demonstrates that respondents are willing to trade off *private* and *community benefits* in favour of Environmental and *financial benefits*. The high value placed on *environmental benefits* (Levels 3 and 4) and the strong negative impact of high-*risk* factors show that while participants prioritize sustainability, they are also careful about the associated *risk*s. Therefore, participants are willing to accept trade-offs, mainly when the projects contribute significantly to Environmental sustainability.

Test. Respondents are willing to pay for project attributes that improve living conditions (project alternatives 2, 3, 4) and sustainability (project alternatives 3 and 4).

While respondents are willing to pay for sustainability-related attributes (e.g., *environmental benefits* at Levels 3 and 4), the data indicate that *private benefits* (improving living conditions) are not as highly valued. Participants are willing to accept trade-offs in *private* and *community benefits* in favour of *environmental* and *financial benefits*. However, it is important to note that improving living conditions is closely tied to *financial* and *environmental benefits*, as enhancing the community's *financial* well-being and contributing to sustainability indirectly support better living conditions. Thus, while direct *private benefits* may not be prioritized, the broader improvements in *financial* and *environmental benefits* enhance overall living conditions in the community.

5.23 Conclusion

The findings from this DCE provide valuable insights into how the community of El Zangarro evaluates alternative energy projects. Respondents prioritize *environmental* sustainability and *financial benefits*, showing an evident willingness to pay for these attributes while remaining *risk*-averse. Private and *community benefits* are secondary considerations, and cost plays a vital role in decision-making. The community is willing to accept trade-offs, especially regarding projects contributing to *environmental* sustainability and *financial* improvements. This analysis supports the statement that participants are willing to trade off certain *benefits* for sustainability, and the test is partially supported, as improving living conditions is closely related to *environmental* and *financial benefit*s, even though direct *private benefits* are not as highly prioritized.

These insights can guide future project designs, focusing on delivering high *environmental* and *financial benefits* while managing *risk*s and costs and ensuring community support for alternative energy projects in El Zangarro.

5.24 Main Hypothesis

The conclusion to the hypothesis that sustainability and renewable energy will be relevant to the community if it relates to its ultimate goals is supported by the study's findings. El Zangarro's community values *environmental* sustainability and *financial benefits*, particularly when these are tied to improving their living conditions. The Discrete Choice Experiment (DCE) results confirm that respondents are willing to accept trade-offs, prioritizing projects with high *environmental* and *financial benefits*. However, while *private* and *community benefits* are valued, they are considered secondary to larger goals such as *environmental* preservation and *financial* well-being.

This result indicates that the community's support for sustainability and renewable energy projects is strong, especially when they align with their broader goals of improving quality of life, *environmental* preservation, and financial stability. Therefore, the hypothesis is confirmed: sustainability and renewable energy are relevant to the community when tied to them.

5.25 Implications for Future Actions

1. Prioritize Projects with High *Environmenta*l and *Financial Benefit*s
Focus on Sustainability and *Financial* Impact: The DCE results indicate that community members highly value projects with significant *environmental benefits* and *financial* improvements. Therefore, future alternative energy projects should emphasize these attributes to ensure greater community support.

5.26 . Implement Robust Risk Management Strategies

Address *Risk* Aversion: as the DCE Reveals. The community's aversion to high-*risk* scenarios suggests that future projects must include strong *risk* management measures. Risk mitigation is essential for the project's success, particularly for biodigesters, as they are sensitive to fluctuations in manure availability and climate change impacts. Mitigation strategies could include securing alternative organic waste sources, implementing robust maintenance protocols, training communities in adaptive management and maintaining community engagement to reduce risks and enhance long-term viability. Clear communication about mitigating *risk*s will be crucial for gaining and maintaining community trust and support.

5.27 Balance Costs with Perceived Benefits

Manage Costs Effectively: Higher project costs were shown to decrease the likelihood of community support. It is important to ensure that the *project's benefits* are perceived as outweighing the costs. This result could involve exploring cost-reduction strategies or providing financial incentives to make the projects more attractive to the community.

5.28 Design Projects with Tangible *Benefits*

Provide Clear Returns for Participation: The DCE results indicate that community members are more likely to support projects that offer direct, tangible *benefits*, such as *financial savings* or *environmental improvements*. Future projects should be designed to articulate and deliver these *benefits* to participants.

These implications suggest that future actions should focus on developing projects that align closely with the specific attributes evaluated and prioritized in the DCE, particularly maximizing Environmental and *financial benefit*s while managing *risk*s and *costs* effectively. This targeted approach will be vital to ensuring the success of alternative energy projects in El Zangarro.

5.29 Chapter Summary

Chapter Five explores the social feasibility of implementing renewable energy projects in El Zangarro community, focusing on the research questions: How do community members perceive and evaluate the *benefits* of alternative energy projects? Moreover, what trade-offs are involved in community preferences for these scenarios? The analysis draws from three key questionnaires and a Discrete Choice Experiment (DCE) to provide comprehensive insights into these questions.

The first questionnaire, an exploratory tool, was administered to gather initial perceptions of renewable energy projects. Participants identified water scarcity and unreliable electricity as the main issues affecting their daily lives. They showed interest in sustainable solutions but expressed concerns regarding their practical implementation. This questionnaire provided baseline data on the community's understanding and expectations for renewable energy.

The second questionnaire was distributed after the community received detailed information about the proposed projects—installing a larger water pump, biodigesters, and solar panels. The demographic data from this questionnaire showed that 32.4% of participants were aged between 18 and 34, reflecting high youth involvement in the decision-making process. Additionally, 48.5% of respondents were aged between 35 and 59, highlighting the strong representation of middle-aged adults. A smaller portion, 14.7%, were under 18 years old, showing that even younger individuals were engaged in discussing the future of the community's energy projects. Most participants (70%) were married, and 62.35% had completed secondary education or higher. The diversity of occupations, ranging from farming to housekeeping, mirrors the community's rural character.

Regarding project preferences, the second questionnaire revealed strong support for *environmental* improvements. For example, 70.59% of participants rated the reduction of flies as very important, and 72.94% prioritized sewage cleanup as a critical *benefit* of the biodigester project. Additionally, 62.35% highlighted the importance of reducing bad odours caused by animal manure. Support for solar panels was overwhelming, with 96.47% of respondents in favour of the project, emphasizing the community’s enthusiasm for renewable energy solutions.

The third questionnaire, explicitly aimed at livestock farmers, focused on their willingness to participate in the biodigester project by contributing animal manure. The responses indicated strong support, as farmers recognized the dual *benefits* of waste management and access to biogas and fertilizer. This group saw the biodigester project as an opportunity to improve local sanitation and gain *financial benefit*s from renewable energy.

When addressing the central research questions, the results from the questionnaires and DCE show that community members strongly value *environmental benefits*, particularly reductions in greenhouse gas emissions, and are willing to pay for projects that contribute to long-term *environmental* and *financial benefits*. However, the findings also highlight cost and *risk* as critical factors. Participants were willing to accept trade-offs, mainly moderate cost increases, if the projects provided clear *benefits*, such as *environmental improvements* and *financial savings.* Nevertheless, high-*risk* or high-cost alternatives were less favoured unless significant perceived gains offset these *risk*s.

In conclusion, this chapter demonstrates that for renewable energy projects to be socially feasible in El Zangarro, they must balance sustainability with affordability and manageable *risk*s. The biodigester project emerged as a favoured solution due to its *environmental*, *financial*, and *social benefits*. These findings provide essential insights for successfully implementing renewable energy initiatives that align with the community's values and priorities, especially when considering the necessary trade-offs between *costs*, *risk*s, and *benefits*.

CHAPTER SIX

6. Discussion

This research aimed to answer four central questions: *What is the notion of sustainability in the community of El Zangarro? How does the community's notion of sustainability fit with community priorities? How do community members perceive and evaluate the benefits of alternative energy projects? What trade-offs are involved in the alternative project scenarios, and what are community members' preferences for these scenarios?* By analyzing data from three key questionnaires and a Discrete Choice Experiment (DCE), this study provides valuable insights into the community's social, technical, and *financial* feasibility of renewable energy projects.

6.1 The Notion of Sustainability in the Community

Regarding the first research question—*What is the notion of sustainability in the community of El Zangarro?* —Questionnaire 1 and Questionnaire 2 findings demonstrate that most respondents view sustainability as an important issue. Responses to questions such as Q3, Q6 (Questionnaire 1), Q6a, Q6b, Q6c, and Q31 (Questionnaire 2) reveal that over 50% of the community members consider sustainability a critical factor in improving their living conditions. This result indicates a strong understanding among the community of the importance of sustainability and its role in addressing local challenges such as environmental degradation, water scarcity, and energy inefficiency.

6.2 Sustainability and Community Priorities

The second research question—*How does the community's notion of sustainability fit with community priorities?* —was addressed through responses in both Questionnaire 1 (Q1, Q2) and Questionnaire 2 (Q7a, Q7b, Q8a, Q8b, Q24, Q25, Q27). The data suggest that respondents consistently connect sustainability issues to broader community priorities, such as *financial* and *social benefits*. Most respondents identified sustainability as a key community problem and agreed to integrate sustainability into projects that provide *financial* and *social benefits*. For instance, respondents viewed water and waste management improvements as top priorities, emphasizing the alignment between sustainable energy initiatives and the community's broader goals.

6.3 Perceptions and Evaluation of Alternative Energy Projects

Concerning the third research question—*How do community members perceive and evaluate the benefits of alternative energy projects?* —the findings from the DCE and the post-information questionnaires reveal a strong preference for projects that offer *environmental* and *financial benefits*. Solar panels, for example, received overwhelming support, with 96.47% of respondents favouring their installation. The community perceives the reduction of environmental issues, such as sewage cleanup (72.94%) and fly reduction (90.59%), as direct *benefits* of the proposed renewable energy projects. Additionally, the biodigester project received support from 91.67% of livestock farmers, highlighting the perceived *benefits* of biogas and fertilizer production.

6.4 Trade-offs and Community Preferences

The fourth research question—*What trade-offs are involved in the alternative project scenarios and community members' preferences for these scenarios?* —was addressed through the DCE, which revealed that community members are willing to accept certain trade-offs in favour of sustainability. Respondents were willing to pay for project attributes that improved living conditions and supported sustainability, particularly for alternatives 2, 3, and 4. However, *cost* and *risk* remained critical factors. While many respondents were open to moderate increases in cost for projects with clear *benefits*, such as solar panels and biodigesters, there was hesitancy toward projects perceived as high-*risk*, such as using biogas derived from animal manure. These findings underscore the importance of balancing cost, *risk*, and *benefit* to gain broader community support.

6.5 Limitations of the Study

The model used in this study is flexible and can be adjusted to meet the needs of other communities, making it a useful tool for understanding preferences for renewable energy projects. However, there are some limitations. The findings are specific to El Zangarro and may not apply to communities with different priorities. While the sample reflects the community well, more participants would strengthen the results. Lastly, the study focuses on certain technologies and may not include other renewable energy solutions that could be more relevant in different regions.

6.6 Comparison with Existing Literature

Cohen et al. (2016) found that large-scale expansion of overhead transmission lines, vital for integrating renewable energy sources and securing the electricity supply in the European Union's low-carbon strategy, faces less resistance when locals are informed about the positive economic or *environmental* impacts. In contrast, projects offering only *community benefits*, like compensation or public works, tend to face more opposition. Similarly, Cohen et al. (2021) found that while beliefs in renewable energy's *environmental benefits* and identification as environmentalists influence individuals' willingness to invest in community renewable energy (CRE) projects, the economic impact, particularly job creation, serves as an even stronger motivator for acceptance. This result suggests that although *environmental benefits* are valued—allowing individuals to express their *environmental* identity—the promise of *economic benefits,* especially jobs, is a more compelling driver. This thesis aligns with these findings, showing that projects highlighting *financial* and *environmental benefits* tend to receive greater acceptance than those focusing solely on *community benefits*. This outcome underscores the importance of balancing *environmental* and economic appeals, with a stronger emphasis on economic incentives, to gain broader community and investor support for renewable energy initiatives.

In a related context, Rahman et al. (2019) found that affordability and community involvement are crucial to adopting anaerobic digesters in rural Bangladesh. They highlight that *economic benefit*s (cost savings) and social factors (fostering relationships within the community) play a significant role in the success of community-based anaerobic digestion (AD) systems. This research parallels the findings in El Zangarro, where community engagement and the availability of affordable renewable energy options were essential for the acceptance of technologies like biodigesters.
Hettiarachchi et al. (2018) also emphasized biogas production's *environmental* and *economic*

*benefit*s, especially in waste management in developing countries. Their study highlighted that biogas production contributes to energy generation and supports sustainable organic waste management, reducing landfill waste and environmental impact. This result aligns with the positive reception of biodigesters observed in this study, as both approaches leverage biogas technology to enhance waste management and energy production.

Furthermore, Abdullah and Mariel (2010) conducted a choice experiment in Kenya to estimate the willingness to pay (WTP) for improved electricity services in rural areas. They found that households were willing to pay extra for better energy reliability to avoid frequent and prolonged outages. This willingness to pay for enhanced reliability in electricity services supports the notion that communities value improvements that directly impact their quality of life. This aligns with this study's findings regarding the community's willingness to invest in renewable energy projects to improve their quality of life.

Mancini and Raggi (2022) discussed the scalability of biogas projects, noting that social acceptance is a crucial non-technical barrier. Local trust and socio-cultural context play a significant role in their social acceptance. This outcome aligns with the strong support for biodigesters in this study, where trust in local leaders and the project's long-term *benefits* was vital in gaining community support.

While this study reaffirms the *financial* and *environmental* drivers of technology adoption in rural areas, it uniquely contributes by exploring the specific trade-offs the community is willing to accept, particularly in *cost* and *risk*. Additionally, the willingness-to-pay analysis in this study provides deeper insights into how these factors influence decision-making at the community level. These findings make a novel contribution by highlighting the specific trade-offs that rural communities like El Zangarro are willing to accept and offer a more granular understanding of the balance between cost, *risk*, and sustainability *benefits* in community decision-making.

6.7 Policy Implications

The findings of this study suggest that policymakers should consider implementing programs that offer clear and tangible *financial* incentives for adopting renewable technologies in rural communities as community projects. Incentives such as direct subsidies, low-cost financing programs, or tax reductions for technologies like biodigesters and solar panels can encourage rural communities to embrace these energy solutions. Furthermore, it is essential to involve community members from the early stages of the project, ensuring that energy solutions are technically feasible and socially and culturally accepted.

This participatory approach should include community workshops, open consultations, and the creation of local committees to oversee project progress, ensuring that the projects reflect the community's actual needs and priorities. The study has shown that trust and the perception that the project will benefit the community are crucial to its acceptance. Trust is evident in the community when members actively participate in the project, demonstrating confidence in its goals and processes. This participation reflects successful engagement, where community members feel heard and valued and see their input incorporated into decision-making. When people willingly contribute their time, resources, or knowledge to the project, trust has been established through meaningful and transparent engagement efforts. Therefore, policymakers should promote a collaborative approach to local governance.

Finally, ensuring proper integration between local energy policies and national frameworks is critical to maximizing the long-term *benefits* of renewable energy projects. This participatory approach can build community trust and enhance project acceptance, ensuring long-term sustainability.

6.8 Practical Implications for Project Implementation

The findings of this research have important practical implications for the successful implementation of renewable energy projects in rural communities. For instance, targeted educational campaigns are essential for addressing concerns related to unfamiliar technologies, such as biogas from human waste. Policymakers and project developers should prioritize transparent communication and provide detailed information on these technologies' *environmental* and *financial benefit*s to build trust within the community. As identified in this study, the logistical challenges associated with manure collection for the biodigester project require coordinated efforts between local stakeholders and external partners. Ensuring that the *benefits*—such as biogas and fertilizers—are equitably distributed will be vital to sustaining community support.

6.9 Future Research Directions

Future research could build upon the findings of this study by exploring the long-term impacts of renewable energy project implementation in El Zangarro and similar communities. Specifically, longitudinal studies could assess how community perceptions and willingness to pay evolve after implementing the projects. Comparative studies in other rural communities in Mexico and internationally could also provide a broader understanding of how social, economic, cultural, and environmental factors influence renewable energy adoption. Given the reluctance of some community members to accept biogas from human waste, further research is needed to explore how *risk* perception and cultural values affect the adoption of unconventional energy technologies. Finally, more in-depth analyses of renewable energy projects' technical and logistical aspects, such as integrating solar panels into existing infrastructure, would provide valuable guidance for future project developers.

CHAPTER SEVEN

7. Conclusion

7.1 General Conclusions

This research has provided comprehensive insights into the social acceptability, technical feasibility, and *financial* viability of renewable energy projects in the rural community of El Zangarro, Mexico. The study explored four key questions through Discrete Choice Experiments (DCE) and detailed questionnaires: *What is the community's perception of sustainability? How does this perception align with community priorities? How do community members evaluate the benefits of alternative energy projects?* Moreover, *What trade-offs are the community willing to accept for these projects?* The findings reveal that most of the community perceives sustainability as essential, especially when linked to improving living conditions through better environmental management and *financial benefit*s. This alignment between sustainability and community priorities highlights the readiness of El Zangarro to adopt renewable energy solutions that address key local issues, such as water scarcity and energy insecurity. Solar panels and biodigesters emerged as the most favoured technologies, with strong support from the community for their implementation.

The high willingness to participate in projects like the biodigester (91.67% of livestock farmers) and the overwhelming support for solar panels (96.47% of respondents) demonstrate that the community is open to renewable energy initiatives that promise environmental improvements and *financial* gains. However, the study also identified vital trade-offs the community is willing to consider. *Cost* and *risk* were critical factors influencing decision-making. While the community was willing to accept moderate *cost* increases for projects with clear *benefits*, there was noticeable hesitancy regarding technologies perceived as risky, such as biogas derived from human waste. These findings underline the importance of carefully balancing affordability, risk management, and benefits when designing and implementing renewable energy projects. From a technical and *financial* standpoint, the study shows that renewable energy projects like solar panels and biodigesters are viable for El Zangarro.

Financial metrics, such as favourable Net Present Value (NPV) and Internal Rate of Return (IRR), indicate that these projects offer long-term *financial benefit*s to the community. Solar panels' short payback period makes them particularly attractive. Nevertheless, successful implementation will require addressing technical challenges, such as infrastructure upgrades for solar energy and logistical complexities for biodigester operation.

The study's sample size and the use of participant-provided data offer valuable insights into community preferences. However, future research could expand the sample to capture broader perspectives. Additionally, future studies could benefit from further exploring political and institutional factors that may enhance the feasibility and successful implementation of renewable energy projects in rural areas.

7.2 Institutional and Financial Challenges

One key challenge this research uncovered is the lack of financial instruments tailored to support community-based renewable energy initiatives. Some support programs and agreements are available for ranchers and livestock owners in Mexico, but these are typically targeted at individual projects. These programs often offer subsidies or loans for renewable technologies like biodigesters but are limited to those with access to significant resources or collateral. In contrast, the type of community-based project explored in this study did not find any existing financial instruments suited for communal initiatives. When this research was developed, no instruments were found to support community-based renewable energy projects in Mexico specifically. Financing options for these community projects are virtually non-existent, particularly for low-income rural areas like El Zangarro. Traditional financing mechanisms require collateral, such as land titles or valuable assets, which most of the population in El Zangarro do not possess, making it highly unlikely that they could meet the requirements for standard bank loans. One potential mechanism that could assist communities is the NODESS (Nodes for Social and Solidarity Economy), which exists in Mexico. This system involves forming a cooperative society that could make them eligible for bank loans or grants. However, these options become difficult to access without land titles, which most of the population lacks. As a result, the community remains unable to capitalize on renewable energy projects that could improve their quality of life and financial stability.

Given these barriers, it is crucial to consider alternative financing models that do not require collateral. One potential solution would be the development of a credit framework specifically designed for rural communities, offering loans without the traditional need for land title guarantees. Such a framework could enable communities like El Zangarro to access the funds necessary for implementing renewable energy projects, contributing to their long-term sustainability and energy security. Political action and collaboration between government agencies, financial institutions, and local leaders are required to develop such frameworks. The goal would be to foster a more inclusive financing system, allowing rural communities to participate in the renewable energy transition even without traditional guarantees. By addressing these institutional and financial challenges, communities can better access the resources needed to improve energy security and build resilience through renewable technologies.

7.3 Implications for Policy and Practice

This research guides policymakers, project developers, and community leaders. Aligning renewable energy initiatives with local values and priorities is crucial to ensuring the success of renewable energy projects in rural areas like El Zangarro. Targeted educational campaigns are necessary to build trust and understanding, especially for technologies perceived as unconventional or risky. Transparent communication about these projects' *environmental* and *financial benefit*s will be essential for gaining broad community support.

Moreover, ensuring equitable distribution of the *benefits*—such as access to biogas and fertilizers—will be vital to sustaining long-term engagement and support from all community members. Collaborative efforts between local stakeholders, government agencies, and external partners will be critical for overcoming logistical and technical challenges.

These findings are consistent with previous research on renewable energy adoption in rural communities, highlighting the importance of aligning projects with local priorities. However, this study contributes novel insights by identifying specific trade-offs that communities are willing to accept, particularly regarding the balance between *cost*, *risk*, and long-term sustainability *benefits*.

7.4 Future Research Directions

Future research could explore the long-term impacts of implementing renewable energy projects in rural communities like El Zangarro, focusing on evolving community preferences. Additionally, comparative studies across different rural areas would provide valuable insights into the broader applicability of these findings. Understanding the role of governance, policy support, and regulatory frameworks would also offer a clearer picture of the political and institutional factors influencing renewable energy adoption.

7.5 Scalability and Generalizability of the Study

This study presents a framework that can be applied to other rural communities to understand their preferences in sustainability projects. The Discrete Choice Experiment (DCE) used in El Zangarro is flexible and can be easily adapted to different communities. While this study focused on renewable energy technologies like biodigesters and solar panels, the same approach can be used for other projects such as water management or agricultural innovations. The renewable energy solutions—biodigesters and solar panels—are also scalable. These technologies can be introduced in rural areas with similar resources and environmental conditions. They address common problems in rural areas, such as energy shortages and waste management, so they can be used in many locations.

Regarding generalizability, the results from El Zangarro offer valuable insights into what rural communities prioritize in renewable energy projects. El Zangarro shares common characteristics with many other rural communities in Mexico and worldwide, such as reliance on agriculture, limited access to the power grid, small-scale farming, water access challenges, financial constraints, and environmental vulnerabilities. As a result, the financial, *environmental*, and *community benefits* and *risk*s observed in this study are likely to resonate with other rural areas facing similar issues. However, it is important to recognize that cultural and social differences may influence the generalizability of these findings. Therefore, when applying these findings to other regions, it is crucial to consider each community's specific cultural and social contexts.

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Appendix A. Consent Form

UNIVERSITY OF SASKATCHEWAN

Participant Consent Form

You are cordially asked to participate in a research project called Social Acceptability of Renewable Energy: Exploring Community Member's Preferences over Attributes of Energy Projects.

Student Researcher:

Virginia Lucia Moreno de Quevedo, master's Student, College of Graduate and Postdoctoral Studies, School of Environment and Sustainability, the University of Saskatchewan, Saskatoon, Canada.

twy208@usask.ca

Researcher team:

Alejandra González Lona M.Sc., Academic technician, College of Chemical, Electronics and Biomedical Engineering, Science and Engineering division, University of Guanajuato, Leon, Guanajuato, México.

Work phone: (52)477-788-51-00, Alejandra.gonzalez@ugto.mx

Carlos Eduardo Molina Guerrero Ph.D., professor, College of Chemical, Electronics and Biomedical Engineering, Science and Engineering division, University of Guanajuato, Leon, Guanajuato, México.

Work phone: (52)477-788-51-00, cemolina@ugto.mx

Oscar Zapata Ph.D., Assistant Professor, College of Graduate and Postdoctoral Studies, School of Environment and Sustainability, Centennial Chair in Community Energy Development, University of Saskatchewan, Canada.

Work phone: 306-966-1617, oscar.zapata@usask.ca.

What is the background and justification for the project?

3.2) In 2020, a research team from the University of Guanajuato (UG) conducted a workshop. It surveyed a sample of the population of El Zangarro to understand the community's perspective on bioenergy, community participation, and environmental and social issues. This research laid the groundwork for the following research proposal, which aims to measure the community's preferences for environmental, social, and *financial benefits* and *cost*s. It will consider three alternative projects, two of which involve renewable energy.

Why are you invited to this study?

You are invited to participate in this study because you are over 14 years old and live in the community of El Zangarro. The study asks you to state your opinion and preferences about proposed bioenergy projects.

What is this study about?

This study is about community attitudes toward various proposed bioenergy projects. The researchers aim to determine the community members' preferences for the proposed bioenergy projects. Your participation, together with the others, will allow the researchers to answer the following questions:

-What is the idea of sustainability in El Zangarro?

How does the community idea of sustainability fit with community priorities?

-How do community members perceive and value the *benefits* of bioenergy projects?

-What are the trade-offs involved in alternative project scenarios and community members' preferences for these scenarios?

Am I free to participate?

Your participation is voluntary, meaning it is up to you to decide whether or not you wish to participate in the study. If you choose to participate, we will ask you to assist in a community workshop and answer some questions. If you decide not to participate, your relationship with people on the research team will not be affected.

Who can participate?

The target population is people over 14 years old living in El Zangarro. The participation of youth and adults (especially those from 14 to 30 years old) is encouraged.

How will the information be gathered?

The information will be collected through a workshop and recorded via video. At the beginning of the workshop, participants will be allowed to communicate and clarify their doubts about the process. Second, an exploratory questionnaire will be distributed to the participants to establish the community members' main preferences, interests, and expectations related to sustainable energy issues. Third, the research team will explain the proposed bioenergy projects and the energy produced. The *financial, environmental, and* social *benefits(private and community)*, *risk*s, and *cost*s, as well as the community engagement associated with these *benefits*, were also explained. Fourth, structured conversations will be held, and the participants will be asked to establish their preferences by selecting a set of different scenarios.

The exploratory questionnaires will be distributed in two ways: the onsite survey will be completed with paper and pencil. The internet surveys will be sent to the participants' e-mail accounts if they cannot attend the workshop. Survey Monkey will be used, and the data will remain on servers in Canada. The SurveyMonkey privacy policy link is https://www.surveymonkey.com/mp/privacy/

No personal data will be collected while linking the responses to an identity. However, the email addresses of individuals participating in the online survey will be collected solely for sending the survey. Once the surveys have been sent, the email list will be destroyed.

The total time for the workshop is estimated to be two hours maximum.

The interventions will be carried out by trained and specialized personnel, including some researchers, as mentioned on the first page of this document.

Is the study funded?

No

Are there any risks to participating?

You will not face any known or expected risks if you participate in this study.

Are there any *benefits*?

If you chose to participate in this study, there might not be direct *benefits* to you. It is hoped that the data collected from the workshop could establish the basis of the type of engagement the community members are willing to partake in if any of the proposed projects are settled.

Is there going to be pay for my participation?

No compensation will be provided.

Will confidentiality be respected?

Your wishes about confidentiality will be respected. The study data will be stored with password protection and separately from the consent form, preventing any association with your name. The provided data will be disseminated in several documents, such as a thesis, articles, conferences,

and reports to the community, but no personal identifying information will
be included in any report. The data will be summarized and reported. Only the research team members will have access to both information (the consent form and the study data). If there is a need to report explicit references, you have the right to decide whether to use an identifier that can be a pseudonym.

The information will be collected with no identifiers of any sort. Participants will not be asked to put their names on the surveys. Only email will be asked for the online survey; the list will be destroyed after the survey has been sent.
Please put a checkmark to give permission.
Please put a checkmark beside only one option below.

I want my identity to be kept private.	
You may use a pseudonym to refer to me if there is a need for explicit reference. I wish my identity to be confidential.	
You are welcome to cite me and use my name if there is a need for explicit reference.	

<u>How and where will the information be kept?</u>
The student researcher will collect the questionnaire's paper copies during the workshop and move them to the PI's office for storage. All physical data and forms will be kept in a locked drawer in the PI´s locked University of Saskatchewan office.

The Principal Investigator will keep the electronic study data acquired during and after the analysis on his Usask OneDrive account. Data will be shared through this account with the student/other research team members, who will have remote access. Only the researchers mentioned in this consent form can access the information. Five years after the publication of the data, all information obtained from it will be deleted using a means that does not permit its recovery.

<u>What will happen if I choose to stop my participation in the study?</u>
Participation in this study is optional; you may respond to the questions you feel comfortable with.

You are free to leave the research project at any time and for any reason without having to justify it. You may withdraw from the research project for any reason without penalty of any sort. Should you wish to withdraw, you may leave the group meeting at any time; however, data that has already been collected cannot be withdrawn as it forms part of the context for information other participants provide. If you enter the study and then decide to withdraw later(post-workshop), the data collected from you will not be destroyed (physical data, all electronics, and records associated with the workshop and questionaries).

Survey data cannot be withdrawn once submitted since their names will not be connected to their data. Only emails will be asked for online surveys; the list will be destroyed after the surveys have been sent.

Will I be told how the study turned out?

Once the information is analyzed and the thesis document is written, a workshop will be held in the community to share the research results. You can request a copy of the findings by contacting any researchers mentioned in this document.

Whom do I contact for more information?

If you have any questions or concerns, please contact the researchers using the details provided on the first page of this permission form. The University of Saskatchewan Research Ethics Board has determined that this study meets ethical guidelines.

The University of Saskatchewan Behavioral Research Ethics Board has reviewed and approved this study.

The University of Guanajuato Ethics Committee has reviewed and approved this study, which complies with the General Health Law and its corresponding regulations for research involving human subjects. Reference number assigned by CEPIUG:___________

5.2) Dr. María Eugenia Garay Sevilla

Chair of the Ethics Committee for Research at the University of Guanajuato

By e-mail: etica@ugto.mx

If you have any concerns about your rights as a participant in this study, feel free to contact the ethics office.

By mail: ethics.office@usask.ca

By phone:1(888) 966-2975 toll-free

Dr. María Eugenia Garay Sevilla

Chair of the Ethics Committee for Research at the University of Guanajuato

By e-mail: etica@ugto.mx

b. Consent

Consent: *Select the appropriate options from below:*

COVID-19 protocol: Masks and sanitizer will be offered at the workshop for participants who wish, and physical distancing will be encouraged.

Signed Consent:

Signing this document confirms the following:

I have read and understand the description provided in this document.

I had a chance to ask questions, and those questions were answered.

I give my permission to take part in the research project.

I can stop participating in this study anytime for any reason, and my choice will not change anything.

I was given a copy of this consent form for my records.

I have been provided with all the necessary information about the research project and the reason for my participation. Likewise, all my doubts have been addressed, and the possible risks and *benefits* of my participation have been explained to me. The responsible researcher has assured me that I will not be identified in presentations or publications resulting from this study and that my privacy-related data will be handled confidentially.

Therefore, I give my consent to participate in the project.

______________________	______________________	____________
Name of Participant	*Signature/fingerprint*	*Date*

______________________________ ______________________

Principal Researcher Name and Signature *Date*

Name of witness 1 and signature/fingerprint: ____________________________

Contact information: ____

*Date:*_____________

Name of witness 2 and signature/fingerprint: ______________________________

Contact information: ____

Date: _____________

Name of the principal investigator and signature: ___________________________

A copy of this consent will be left with you, and the researcher will take a copy.

Oral Consent: *(If Applicable):*

If consent is obtained orally, this must be documented. For example, the consent form is dated and signed by the researcher:

Oral Consent: By signing and dating below, I [insert name of researcher] confirm that I read and *explained* this Consent Form to the participant before getting the participant's consent, and the participant knew what it said and seemed to understand it.

Yes/No Oral consent was audio recorded (please put a checkmark)

_____________________________ _____________________________ _______________

Name of Participant. Signature/Fingerprint *Researcher's name and Signature* *Date*

This part must be completed by the researcher (or their representative):

I have explained to Mr./Ms.____the nature and purposes of the research; I have explained the risks and *benefits* involved in their participation. I have answered questions to the best of my ability and asked if they have any doubts. I acknowledge that I have read and understand the relevant regulations for conducting research with human subjects and adhere to them.

Upon completion of the question and answer session, this document was signed.

___________________________________ _________________________

Researchers Signature Date

Appendix B. Minor Assent Form (Ages 14 to 17)

Place and Date: ______________________________

Hello, my name is Virginia Moreno. We are conducting a study to understand the community's preferences and would like to ask for your support.

We kindly request your participation in a research project called Social Acceptance of Renewable Energy: Exploring Community Members' Preferences Regarding Energy Project Attributes.

Why are you invited to this study?

You are invited to participate in this study because you are over 14 years old and live in the El Zangarro community. The study asks for your opinions and preferences regarding proposed bioenergy projects.

What is this study about?

This study aims to determine the community's preferences for various proposed bioenergy projects. In general, the researchers seek to understand community members' preferences for specific proposed bioenergy projects. Your participation, along with others, will enable the researchers to address the following questions:

1) What is the concept of sustainability in El Zangarro?

2) How does the community's idea of sustainability align with community priorities?

3) How do community members perceive and value the *benefits* of bioenergy projects?

4) What are the trade-offs involved in alternative project scenarios, and what are community members' preferences for these scenarios?

Your participation in the study will involve attending a video-recorded workshop. At the beginning of the workshop, you will have the opportunity to ask questions and seek clarification about the process. Secondly, an exploratory questionnaire will be distributed to establish community members' key preferences, interests, and expectations related to sustainable energy issues. Thirdly, the research team will explain the proposed bioenergy projects, including the energy produced, financial, environmental, and social *benefits*, financial *cost*s, and community engagement associated with these *benefits*. Fourthly, structured discussions will occur, and you will be asked to express your preferences by selecting from different scenarios.

The questionnaires will be distributed in two ways: on-site surveys will be completed with paper and pencil, while online surveys will be sent to participant's email accounts in case they cannot attend the workshop. Survey Monkey will be used, and the data will be stored on servers in Canada. SurveyMonkey privacy policy link is https://www.surveymonkey.com/mp/privacy/

No personal data will be collected while linking the responses to an identity. However, the email addresses of individuals participating in the online survey will be collected solely for sending the survey. Once the surveys have been sent, the email list will be destroyed.

The total time for the workshop is estimated to be a maximum of two hours.

You will not face any known or expected risks while participating in this study, and there might not be direct *benefits*. It is hoped that the data collected from the workshop could establish the basis of the type of engagement the community members are willing to partake in if any of the proposed projects are settled.

Your confidentiality will be respected. Study data, password-protected and separate from consent forms, will not be linked to your name. Information will be shared in documents like a thesis, articles, and reports, sans personal details. Only the research team will access both the consent form and de-identified data.

The student researcher will collect paper questionnaires during the workshop and store them in the PIs locked in the University of Saskatchewan office. Physical data will be kept in a locked drawer. Electronic study data will be stored on the PI´s Usask OneDrive account and accessible to authorized team members. Access is restricted to researchers, as mentioned in the consent form. Five years after any publication of findings, all data will be securely deleted.

Your participation in this research is voluntary, and you can choose which questions to answer. You may withdraw from the research project for any reason without penalty of any sort. If you decide to withdraw, collected data cannot be removed as it contributes to the overall context.

If you participate and you later decide to withdraw post-workshop, the collected data will not be destroyed. Survey data, once submitted, cannot be withdrawn, but names will not be linked to the responses. Email addresses collected will be asked for online surveys; the list will be destroyed after the surveys have been sent.

Your participation in the study is voluntary, which means that even if your parent or guardian has agreed to your participation, you can still choose not to participate. It is your decision whether or not to take part in the study. It is also important for you to know that if at any time you decide you no longer want to continue with the study, there will be no problem, or if you do not want to answer a particular question, that is perfectly fine, too. This information will be kept confidential, meaning that we will not share your answers or results with anyone without your permission; only the members of this study team will know. If you agree to participate, please place an (X) in the box below that says, I want to participate and write your name. If you do not wish to participate, leave it blank and do not write your name.

[ ]I want to participate

Name: ____

Name and signature of the person obtaining assent: _____________________________________

Appendix C. Questionnaire 1.

1. What are the most important issues affecting your community? Please mention it in order of importance (3 to 5 maximum)

2. List in order of importance from 1 to 5, with one being the most important to you.

   a. Generate income and save. _____

   b. Improve environmental quality and take care of nature in the community. _____

   c. Improving children's education ________

   d. Improve community conditions. _____

   e. Have a good relationship with my neighbours____

3. How important do you consider protecting the environment and nature?

   a. Very important

   b. Important

   c. Moderately important

   d. Of little importance

   e. Unimportant

   f. Do not know

4. How annoying is it not to have water every other day?

   a. Very annoying

   b. Pretty annoying

   c. Moderately annoying

   d. It is a little annoying

   e. Not annoying

5. Why is it annoying not to have water every day?

6. Would you like to have a daily water supply in your house?

   a. Yes

   b. No

Why?

7. How would you benefit from having a water supply every day?

8. I am willing to pay a higher fee for having a water supply every day

   a. I agree.

   b. I moderately agree.

   c. I agree a bit on this.

   d. I almost disagree.

   e. I disagree.

9. Do you have an elevated water storage tank at home?

   a. Yes

   b. No

10. If you have an elevated water storage tank at home, what size is it?

    a. Yes, the size is: _______________

    b. No, I do not have it.

11. Do you have an underground water storage tank at home?

    a. Yes

    b. No

12. If you have an underground water storage tank at home, what size is it?

    a. Yes, the size is: _______________

    b. No, I do not have it.

13. Have you heard that energy could be generated from animal manure?

    a. Yes

    b. No

14. Have you heard that energy can be generated from human excrement?

    a. Yes

    b. No

15. Would you object to using energy produced from human excrement?

a. Yes

b. No

c. I am not sure

Why?

16. Would there be any objection to using energy produced from animal manure?

a. Yes

b. No

c. I am not sure

Why?

17. Do you have any concerns or doubts about using fertilizer from human feces in the field?

a. Yes

Explain:

b. No

18. Would you have any concerns or doubts about using fertilizer from animal manure in the field?

a. Yes

Explain:

b. No

19. What would you worry about using fertilizer produced from human feces? (cross out all the ones that apply to your case)

a. Nothing

b. My health

c. The smell

d. I would not feel comfortable

e. What People Say

f. The cost

g. Other___ Explain:

20. What would you worry about using fertilizer produced from animal excrement?

a. Nothing

b. My health

c. The smell

d. I would not feel comfortable

e. What People Say

f. The cost

g. Other___ Explain:

21. Would you object to using cooking gas produced from animal manure?

a. Yes

b. No

c. I am not sure

Explain:

22. Would you object to using cooking gas produced from human excrement?

a. Yes

b. No

c. I am not sure

Explain:

23. What would you worry about using cooking gas produced from human excrement?

a. Nothing

b. My health

c. The smell

d. I would not feel comfortable

e. What People Say

f. The cost

g. Other___ Explain:

24. Have you heard that you could generate electricity from the sun?

a. Yes

b. No

25. Would you be inconvenienced by using electricity produced from the sun?

a. Yes

b. No

c. I am not sure

Why?

26. What would you worry about using electricity produced by the sun?

a. Nothing

b. My health

c. The smell

d. I would not feel comfortable

e. What People Say

f. The cost

g. Other___ Explain:

27. Do you know what bioenergy is (such as biogas or biofuel)?

a. Yes

Explains:

b. No

28. Do you know what a biodigester is?

a. Yes.

Explains:

b. No

29. What are the primary uses of electricity in your home?

a. Appliances

b. bomb

c. Television

d. Computers and electronic devices

e. Foci----

f. washing machine

g. Other: _____

30. What would be the main uses of energy in your work?

a. Pump

b. Work tool

c. Work equipment (refrigerator, oven, mill)

31. Have you had an outage in your home in the last three months?

a. Yes

b. No

32. Did you know what was the reason?

a. Problems with CFE

b. Electric wire damage at home

c. Other. Explain: _________

33. How long has it taken for the power to come back on?

a.

b.

34. Has your home run out of water in the last three months?

a. Yes

b. No

35. How long has your home run out of water?

36. In my home, LP gas is used for cooking.

a. Always

b. Very frequently

c. Often

d. Occasionally

e. Almost never

f. Never

g. I do not know. Why?

37. In my home, firewood is used for cooking.

a. Always

b. Very frequently

c. Often

d. Occasionally

e. Almost never

f. Never

g. I do not know. Why?

38. Are you planning to migrate to another state or country?

a. Yes

b. No

c. I am not sure

Explain

Appendix D. Questionnaire 2.

1. Do you think the biodigester would benefit your community?
    a. Yes.
    b. No

    Explains:
2. What is the main problem in using biodigester in your community?
3. What *benefits* can the biodigester bring to your community? He mentions two *benefits*.
4. Do you think solar panels would benefit your community?
    a. Yes.
    b. No

    Explains:
5. What *benefits* do you think solar panels can bring your community? He mentions two *benefits*.
6. How important do you consider the following *environmental benefits* (concerning the project)?
    a. Decrease in flies.
        i. Very important
        ii. Important
        iii. Moderately important
        iv. Of little importance
        v. Unimportant
        vi. I do not know.

    Why your answer?

    b. Water cleanliness
        i. Very important
        ii. Important
        iii. Moderately important
        iv. Of little importance
        v. Unimportant
        vi. I do not know.

        Why?

c. Reduction of bad smells derived from manure.
    i. Very important
    ii. Important
    iii. Moderately important
    iv. Of little importance
    v. Unimportant
    vi. I do not know.

    Why?

7. How important do you consider the following financial *benefits* (concerning the project)?
    a. Savings on the electricity bill
        i. Very important
        ii. Important
        iii. Moderately important
        iv. Of little importance
        v. Unimportant
        vi. I do not know.

        Why?
    b. Gas bill savings
        i. Very important
        ii. Important
        iii. Moderately important
        iv. Of little importance
        v. Unimportant
        vi. I do not know.

        Why?
8. It is expected to generate financial surpluses from the project; what should that money be spent on?
9. How important do you consider the following *benefits* for the community?
    a. Benefit to the community park
        i. Very important

ii. Important
iii. Moderately important
iv. Of little importance
v. Unimportant
vi. Dont know.

Why?

b. Benefits to school facilities
    i. Very important
    ii. Important
    iii. Moderately important
    iv. Of little importance
    v. Unimportant
    vi. I do not know.

    Why?

10. Would your neighbours have any problem using electrical energy produced from human feces?
    a. Yes
    b. No
    c. I am not sure

    Why?

11. Would your neighbours have a problem using electrical energy produced from animal dung?
    a. Yes
    b. No
    c. I am not sure

    Why?

12. Do you think your neighbours would have any concerns or doubts about using fertilizer made of human feces in their field?
    a. Yes

    Explain:

    b. No

13. Do you think your neighbours would have any concerns or doubts about using animal manure fertilizer in their fields?
    a. Yes

    Explain:
    b. No
14. What would you worry about using fertilizer produced from human feces?
    a. Nothing
    b. My health
    c. The smell
    d. I would not feel comfortable.
    e. What People Say
    f. Otro___ explains:
15. What would you worry about using fertilizer produced from animal excrement?
    a. Nothing
    b. My health
    c. The smell
    d. I would not feel comfortable.
    e. What People Say
    f. Otro___ explains:
16. Do you think your neighbours would have any problem using cooking gas made from animal dung?
    a. Yes
    b. No
    c. I am not sure

    Explains:
17. Do you think your neighbours have any problem using cooking gas from human excrement?
    a. Yes
    b. No
    c. I am not sure

    Explains:

18. What would you worry about using cooking gas produced from human excrement?

    a. Nothing
    b. My health
    c. The smell
    d. I would not feel comfortable.
    e. What People Say
    f. Otro___ explains:

19. Would you be inconvenienced by using the sun's electrical energy?

    a. Yes
    b. No
    c. I am not sure

    Why?

20. What would you worry about using electrical energy produced by the sun?

    a. Nothing
    b. My health
    c. The smell
    d. I would not feel comfortable.
    e. What People Say
    f. Otro___ explains:

21. Do you think your neighbours would use fertilizer in their crops produced from animal manure?

    a. Yes
    b. No

    Why?

22. Do you think your neighbours would use the fertilizer in their crops produced from human excrement?

    a. Yes
    b. No

    Why?

23. Would you buy cooking gas obtained from manure?

    a. Yes
    b. No

Why?

24. Would you buy cooking gas obtained from human feces?
    a. Yes
    b. No

    Why?
25. Energy production is one of the *benefits* of biodigester. How do you think it will be more convenient to enjoy this benefit?
    a. As a discount on the electricity bill
    b. In some projects for the community
    c. In community savings
    d. Another ______Explain:
26. Seeking the *benefit* of the community: what do you think is convenient for investing the money raised from the project? (give three examples)
    a.
    b.
    c.
27. Which of the following projects do you consider the money raised from the project to be invested?
    a. Neighborhood Park
    b. Free internet access in the community park
    c. School maintenance and restoration
    d. Infrastructure such as streets and paths
    e. As additional income for each family
    f. Other: ______ Explain:
28. Based on what has been explained, would you be interested in participating in the project?
    a. Yes, why?
    b. No Why?
    c. I do not know Why?
29. Would you collaborate with the other community members and staff on the project?
    a. Yes, why?
    b. No Why?

c. I prefer not to answer Why?

30. How easily do you think community members would participate in the project?
    a. Very easy
    b. Easy enough
    c. Moderately easy
    d. Not easy
    e. easy
    f. Dont know.
31. In order to provide all these *benefits*, the biodigester will require maintenance. Who should be responsible for maintenance?
    a. An employee from outside the community
    b. An employee who belongs to the community
    c. A volunteer who belongs to the community
    d. Another, explain:
32. If you were the volunteer, how many hours per week would you be willing to offer for such maintenance?
    a. No
    b. 1
    c. 2
    d. 3
    e. 4
33. If it were not necessary to hire anyone for maintenance, savings would be generated (resource for the project); the savings should:
    a. Be distributed among the inhabitants as additional income.
    b. Invest in infrastructure (construction) for the community.
    c. Other (explains)

34. What is your gender?

35. How old are you?

  a. 1 4-1 7
  b. 18-21
  c. 2 2-25
  d. 26-29
  e. 3 0-35
  f. 36-41
  g. 4 2-49
  h. 50-54
  i. 55-59
  j. 60-64
  k. 65-69
  l. 70-74
  m. 75-79
  n. Over 80
  o. I would rather not say it.

36. What marital status do you have?

  a. Single
  b. Married
  a. Widow(er)s.
  b. Divorced
  c. Separated

37. What is your main occupation?

  a. Housewife
  b. Employee
  c. Student
  d. Farmer/Rancher
  e. Other (specify): _____
  f. I would rather not say it.

38. Besides your primary occupation, do you have any other work?

Yes

a. Housewife
b. Employee
c. Student
d. Farmer/stockbreeder
e. Other (specify): _____

No

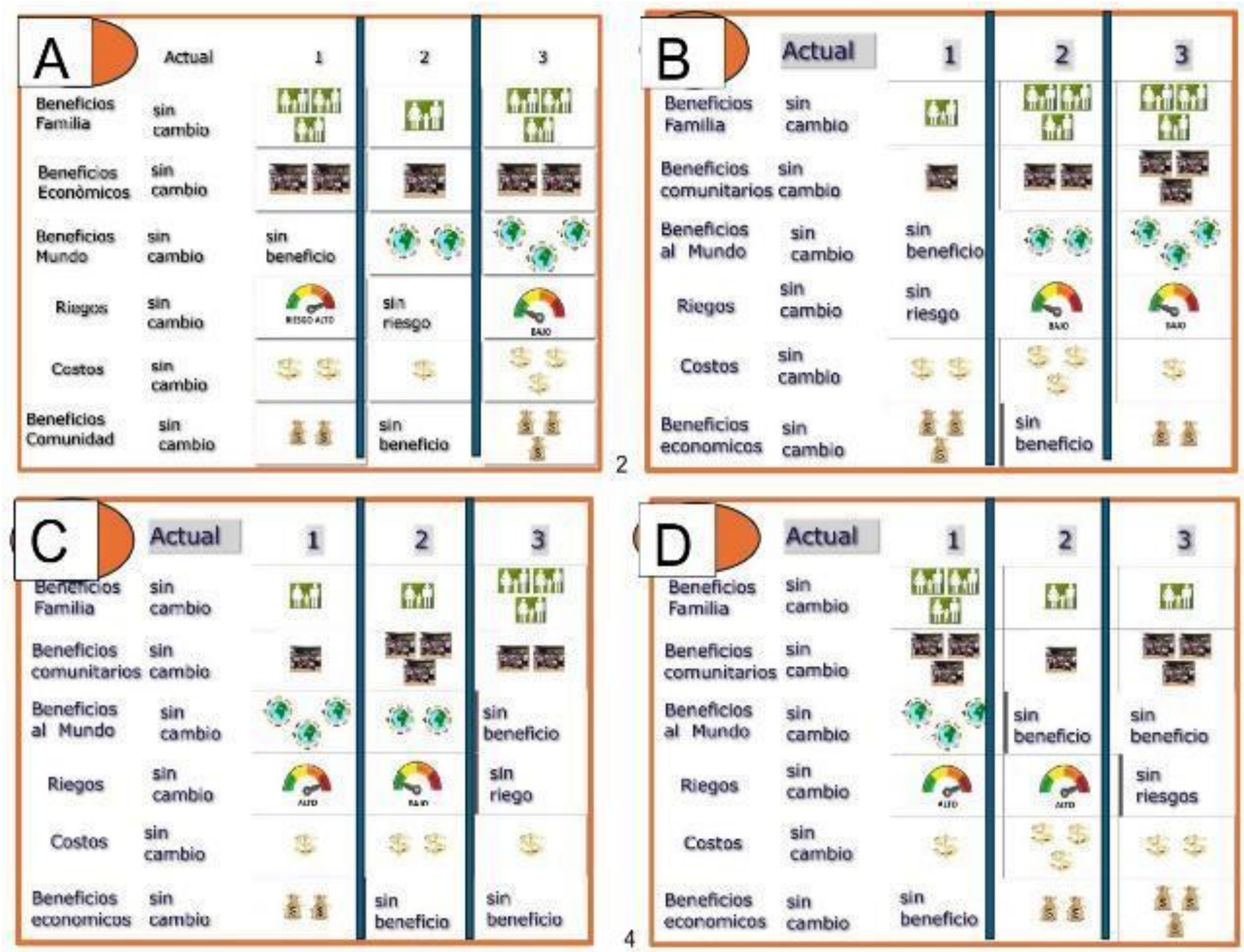
39. Until what grade did you study, or which degree are you learning?

a. I did not study
b. Primary. Until what grade? ____
c. High school. Until what grade? ____
d. High school. Until what grade? ____
e. Technical career. Until what grade? ____
f. Degree. Until what grade? ____
g. Graduate
h. Other. Explain: ____
i. I would rather not say it.

40. How much is your family's income per week?

a. 500-1000
b. 1000-1500
c. 1500-2000
d. 2000-2500
e. 2500-3000
f. 3000-3500
g. I do not know. Explain:

Appendix E. DCE´s Choice Cards Example



Appendix F. DCE´s Choice Cards Options.

A continuación, se mostrarán 16 tarjetas diferentes con cuatro escenarios. Escoge el escenario que prefieres en cada tarjeta.

IMAGEN **A**	IMAGEN **B**	IMAGEN **C**	IMAGEN **D**
1	1	1	1
2	2	2	2
3	3	3	3
Actual	**Actual**	**Actual**	**Actual**
IMAGEN **E**	IMAGEN **F**	IMAGEN **G**	IMAGEN **H**
1	1	1	1
2	2	2	2
3	3	3	3
Actual	Actual	Actual	Actual
IMAGEN **I**	IMAGEN **J**	IMAGEN **K**	IMAGEN **L**
1	1	1	1
2	2	2	2
3	3	3	3
Actual	**Actual**	**Actual**	**Actual**
IMAGEN **M**	IMAGEN **N**	IMAGEN **O**	IMAGEN **P**
1	1	1	1
2	2	2	2
3	3	3	3
Actual	**Actual**	**Actual**	**Actual**

Appendix G. Questionnaire 3

1. Typically, what do you do with manure from your cattle?
    a. I use it as fertilizer.
    b. I sell it.
    c. I leave it on the street for someone else to collect.
    d. Other: (specify)__
2. How many heads of cattle do you have? Describe what you have.
3. How many times a week do you take them out to graze?
4. Do you want to participate by contributing your cattle manure to the biodigester project?
    a. Yes
    b. No
    c. I do not know.
5. How often can you contribute with manure?
    a. Daily
    b. 3 to 5 days a week
    c. One day a week
6. How much manure could you contribute to the project?
    a. ______ kilograms per week
    b. I do not know how much manure I can collaborate with. Explain:
7. Could you transport the manure to the biodigester?
    a. Yes
    b. Depends on distance.
    c. No, I need it to be collected.
8. Would you pay for your animal pen to be cleaned every other day?
    a. Yes
    b. No
    c. I do not know.
9. If you had to pay for the animal pen to be cleaned every other day, you would pay per day:
    a. Less than 20 pesos

b. 20 pesos
c. 30 pesos
d. 40 pesos

10. What *benefit* would you like to receive in exchange for your contribution?
    a. Financial remuneration
    b. Fertilizer
    c. Other: (specify)__

11. Do you identify any problems in the community where the project can help with the income it will generate?
    a. Deforestation
    b. Delinquency
    c. Need for infrastructure.
    d. Lack of water
    e. Garbage problem

    Other: (specify)

12. What is your gender?

13. What is your age?
    a. 18-24
    b. 25-29
    c. 30-34
    d. 35-39
    e. 40-44
    f. 44-49
    g. 50-54
    h. 55-59
    i. 60-64
    j. 65-69
    k. 70-74
    l. 75-79
    m. Over 80

n. I would rather not say it.

14. What marital status do you have?

a. Single
b. Married
c. Widow(er)s.
d. Divorced
e. Separated

15. What is your main occupation?

a. _______________

16. What is your level of schooling?

a. None
b. Primary
c. High school
d. High school
e. Degree
f. Graduate
g. Other (specify): ____
h. I would rather not say it.

Appendix H. Approval Certificate University of Saskatchewan and University of Guanajuato

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics Board (Beh-REB) 29-May-2023

Certificate of Approval

Application ID:	4017
Principal Investigator:	Oscar Zapata — Department: School of Environment and Sustainability
Locations Where Research Activities are Conducted:	This research will be conducted in a rural community named El Zangarro in the municipality Irapuato, Guanajuato State, Mexico., Mexico
Student(s):	Virginia Moreno de Quevedo
Funder(s):	
Sponsor:	University of Saskatchewan
Title:	Social Acceptability of Bioenergy: Exploring Community Members' Preferences over Attributes of Energy Projects
Approved On:	29-May-2023
Expiry Date:	29-May-2024
Approval Of:	Behavioural Ethics Application
	SENS_ Virginia Moreno-Municipal delegate letter El Zangarro.docx
	SENS_ Virginia Moreno-school letter El Zangarro.docx
	SENS_Virginia Moreno-Loudspeaker.docx
	SENS_Virginia Moreno+Questionnaire 1 El Zangarro.docx
	SENS_Virginia Moreo-Questionnaire 2 El Zangarro.docx
	SENS_Virginia Moreno-Questionnarie 3 El Zangarro.docx
	SENS_Virginia_consent_form El Zangarro[17329]final.docx
Acknowledgment Of:	TCPS2 CORE Tutorial Certificates: Virginia Moreno de Quevedo &Alejandra Gonzlez Lona
Review Type:	Delegated Review

Application ID: 4017 Principal Investigator: Oscar Zapata 2 / 2

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board (Beh-REB) is constituted and operates in accordance with the current version of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans TCPS 2 (2022). "The University of Saskatchewan Beh-REB has reviewed the above-named project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this project, and for ensuring that the authorized project is carried out according to the conditions outlined in the current approved protocol. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

ONGOING REVIEW REQUIREMENTS

Any significant changes to your proposed method, or your consent and recruitment procedures must be reported to the Chair through submission of an amendment for Beh-REB consideration in advance of implementation.

To remain in compliance, a status report (renewal of closure form) must be submitted to the Beh-REB Chair for consideration within one month prior to the current expiry date each year the project remains open, and upon project completion. Please refer to the Research Ethics Office website for further instructions and current forms.

Digitally Approved by Pammla Petrucka
Chair, Behavioural Research Ethics Board
University of Saskatchewan

UNIVERSIDAD DE GUANAJUATO

Registro número: CONBIOÉTICA-11-CEI-001-20230127

Guanajuato, Gto. 15 de marzo de 2024

Dictamen CEPIUG 10/2024

Carlos Eduardo Molina Guerrero
Departamento de Ingenierías Química, Electrónica y Biomédica
División de Ciencias e Ingenierías
Campus León
Universidad de Guanajuato
Presente

En relación con el protocolo de investigación en SERES HUMANOS enviado por usted denominado: **Aceptabilidad social de la bioenergía: exploración de las preferencias de los miembros de la comunidad sobre los atributos de los proyectos energéticos** el Comité de Ética para la Investigación de la Universidad de Guanajuato (CEPIUG) se reunió de manera presencial y se revisaron en el mismo los requisitos éticos y normativos nacionales e internacionales aplicables al proyecto y al término de la revisión por consenso dictamen fue:

Aprobado

Dicho dictamen quedó asentado en el acta número **CEPIUG-A01-2024.** El código asignado por el CEPIUG al proyecto es **CEPIUG-P44-2023** para que en lo sucesivo sea citado en los informes y publicaciones. Además, se le informa que debe entregar una carta compromiso dirigida al presidente del **CEPIUG**, incluyendo los apartados del art. 35 del manual de procedimientos del **CEPIUG disponibles en:** https://ugto.mx/investigacionyposgrado/cepiug/.

Asimismo se le informa que el presente dictamen tiene una vigencia de un año y para obtener el refrendo o renovación de la vigencia, deberá presentar un breve informe en formato libre, señalando el grado de avance del proyecto, notificando cambios, reacciones inesperadas, así como cualquier modificación en el proyecto. **Al finalizar el proyecto debe enviar un breve informe indicando si se presentaron efectos adversos o problemas, o si se realizaron cambios al proyecto durante su realización, así como los medios por los cuales se dio información de los resultados a los participantes y a la comunidad científica.**

El CEPIUG se reserva el derecho de revisar el desarrollo del proyecto con el objeto de proteger los derechos y la dignidad de los participantes.

Atentamente
"La verdad os hará libres"

MA. EUGENIA GARAY SEVILLA
LA PRESIDENTA DEL COMITÉ

1|1

COMITÉ DE ÉTICA PARA LA INVESTIGACIÓN DE LA UNIVERSIDAD DE GUANAJUATO
Calzada de Guadalupe S/N Zona Centro; C.P. 36000 Guanajuato,Gto., México.
Registro número: CONBIOÉTICA-11-CEI-001-20230127

CEPIUG

Appendix I. Detailed Calculations for Biogas a Production and Revenue Generation

Biogas

J.1 Biogas Production and Family Support Capacity

- Projected Daily Biogas Production: 81.075 m^3
- Equivalent in LP Gas: 41.37 kg of LP gas
- Updated Consumption Rate: 1.35 kg of LP gas per family per day
- Theoretical Family Support Capacity: 41.37 kg / 1.35 kg per family ≈ 30.64 families

J.2 Revenue Generation from Biogas Sales

1. LP Gas Price: 19.59 MXN per Kilogram (Gobierno de México, 2024)
2. Discounted Sale Price of Biogas: 19.59 MXN × (1 - 0.20) ≈ 15.67 MXN per kilogram
3. Potential Daily Revenue: 15.67 MXN/kg × 41.37 kg = 648.27 MXN per day
4. Potential Monthly Revenue: 648.27 MXN/day × 30 days = 19,448.07 MXN per month

Summary

- Number of Families Supported: Approximately 30.64 families
- Daily Revenue: 648.27 MXN per day
- Monthly Revenue: 19,448.07 MXN per month

Appendix J. Detailed Calculations for Biogas and Biol Production and Revenue Generation

Appendix I. Detailed Calculations for Biogas a Production and Revenue Generation

B.1 Biol Production and Revenue Calculation

- Daily Biol Production per Biodigester: 795 litres
- Total Daily Biol Production (6 Biodigesters): 795 litres × 6 = 4,770 litres per day
- Potential Revenue from Biol Sales: 1 MXN per litre (local market price)

According to the results of questionnaire number three, ranchers are willing to accept Biol as payment for their animal manure, with the amount of Biol provided being proportional to the manure contributed. If the community decides to sell 10% of the total Biol generated, the revenue is calculated as follows:

- Daily Biol Sold: 4,770 litres × 10% = 477 litres per day
- Daily Revenue from Biol Sales: 477 MXN per day
- Monthly Revenue from Biol Sales:

477 MXN/day × 30 days ≈ 14,310 MXN per month

B.2 Combined Revenue Impact

By adding the revenue from Biol sales to the revenue from biogas sales, the project's total monthly revenue is calculated as follows:

- Monthly Revenue from Biogas Sales: 19,448.07 MXN
- Monthly Revenue from Biol Sales: 14,310 MXN
- Total Monthly Revenue:

19,448.07 MXN + 14,310 MXN ≈ 33,758.07 MXN per month

Net Revenue After Costs

After accounting for the monthly operating and maintenance costs of 9,000 MXN, the net monthly revenue would be:

Net Monthly Revenue: 33,758.07 MXN - 9,000 MXN = 24,758.07 MXN per month

Appendix K. Result Table from Questionnaires

Questionnaire 1

Question 1

Table K.1. Frequency of Participants' First Answers

Alternative	Frequency	Percentage (%)
Garbage	31	35.23
Water	31	35.23
pollution	11	12.5
Power	6	6.82
lack of support	2	2.27
street paving	2	2.27
money	1	1.14
drainage	1	1.14
drug addiction	1	1.14
wildfires	1	1.14
social problems	1	1.14

Table K.2. Frequency of Participants' Second Answers

Alternative	Frequency	Percentage (%)
water	32	36.78
garbage	16	18.39
power	14	16.09
stray dogs	6	6.9
drought	5	5.75
green spaces	3	3.45
pollution	2	2.3
delegate	2	2.3
street paving	2	2.3
street lighting	1	1.15
money	1	1.15
drainage	1	1.15
lack of support	1	1.15
wildfires	1	1.15

Table K.3. Frequency of Participants' Third Answers

Alternative	Frequency	Percentage (%)
stray dogs	11	13.1
garbage	10	11.9
power	9	10.71
green spaces	8	9.52
social problems	8	9.52
water	8	9.52
street paving	5	5.95
Pollution	5	5.95
solar heaters	3	3.57
Transportation	3	3.57
education and culture	3	3.57
drainage	3	3.57
drug addiction	2	2.38
health care	2	2.38
infrastructure	1	1.19
money	1	1.19
Drought	1	1.19
Wildfires	1	1.19

Table K.4. Frequency of Participants' Fourth Answers

Alternative	Frequency	Percentage (%)
stray dogs	11	25.58
water	6	13.95
green spaces	5	11.63
street paving	5	11.63
pollution	4	9.3
social problems	4	9.3
garbage	3	6.98
power	2	4.65
health care	1	2.33
drug addiction	1	2.33
education and culture	1	2.33

Table K.5. Frequency of Participants' Fifth Answers

Alternative	Frequency	Percentage (%)
social problems	6	25.0
green spaces	4	16.67
drug addiction	4	16.67
stray dogs	4	16.67
pollution	3	12.5
Infrastructure	1	4.17
Power	1	4.17
street paving	1	4.17

Question 4

Table K.6. How annoying is it to have water one day and not the next?

Answer choices	Responses (%) and Number of Participants
a) Very annoying	40.91%, 36
b) Quite annoying	13.64%, 12
c) Moderately annoying	9.09%, 8
d) Slightly annoying	15.91%, 14
e) Not annoying	20.45%,18

Question 8

Table K.7. Willingness to pay a higher water bill to have direct water every day

Answer choices	Responses (%) and Number of Participants
Strongly agree	27.27%,24
Moderately agree	18.18%, 16
Slightly agree	12.50%,11
Barely agree	10.23%,9
Disagree	31.82%, 28

Question 9

Table K.8. Does your house have an elevated water tank(tinaco)?

Answer choices	Responses (%) and Number of Participants
Yes	89.77%,79
No	10.23%, 9

Question 10

Table K.9. Size of elevated water tanks

Categories	Comments
Small	Small size
Medium	Medium (multiple mentions), 700 litres, 1100 litres (various mentions), 1200 litres
Large	large (multiple mentions), 1500 litres, 2500 litres.
Not Specified	NC (no comment)
Most Common Size	The most frequently mentioned size was 1100 litres, and 1000 litres was mentioned several times. Sizes range from 100 litres to 2500 litres.

Question 11

Table K.10. Do you have a water cistern(aljiber) in your house?

Answer choices	Responses (%) and Number of Participants
Yes	48.86%, 43
No	51.14%, 45

Question 12

Table K.11. Cistern size in household

Categories	Comments
Small	small, three by three meters, NC (no comment), four by four, four by 4 square meters, small, 15x10, two meters by one and a half meters, 2x3 meters, 2 meters by 1.5 meters (multiple mentions), 2x2 cubic meters
Medium	medium (multiple mentions)
Large	large (multiple mentions), 5000 litres, 2000 litres, 10000 litres (multiple mentions), 10,000 litres (multiple mentions), I do not know, the cistern is 2 meters by 2 meters.
Not Specified	NC (no comment), I do not know.

Question 13

Table K.12. Have you heard that energy (cooking gas) can be generated from animal manure?

Answer choices	Responses (%) and Number of Participants
Yes	53.41%, 47
No	46.59%, 41

Question 14

Table K.13. Have you heard that energy can be generated from human excrement?

Answer choices	Responses (%) and Number of Participants
Yes	37.50%, 33
No	53.41%, 47
I am not sure	9.09%, 8

Question 15

Table K.14. Would you have any problem using energy (cooking gas) from human excrement?

Answer choices	Responses (%) and Number of Participants
Yes	41.86%, 36
No	58.14%, 50

Table K.15. Would you have any problem using energy (cooking gas) produced from human excrement? Explain

Reasons	Subcategories	Comments
Reasons for Yes	Hygiene and Health Concerns	It could have bacteria that make you sick, a sour taste, or a smell that would gross me out.
Reasons for No	Environmental and Financial Benefits	It would improve soil contamination., It is a form of bioenergy that benefits us. We would save energy and help the environment. There would be less pollution in seas and reservoirs, saving more gas than natural gas. To be able to cook and use for other things.

Question 16

Table K.16. Would you have any problem using energy (cooking gas) produced from animal manure

Answer choices	Responses (%) and Number of Participants
Yes	24.70%,21
No	75.29%, 64

Table K.17. Would you have any problem using energy (cooking gas) from animal manure? Reason for Responses.

Reasons	Subcategories	Comments
Reasons for Yes	Hygiene Concerns	It may be unhygienic, but it benefits us.
I do not know	Uncertainty or Lack of Knowledge	I have not heard about it because I do not know if it can be used in regular stoves.
Reasons for No	Environmental and Financial Benefits	It would be the best., No, it would be the best., It would be savings in my pocket.

Question 17

Table K.18. Would you have any concerns or doubts about using fertilizer produced from human excrement in the field?

Answer choices	Responses (%) and Number of Participants
Yes	40.70%, 35
No	59.3%, 51

Table K.19. Would you have any concerns or doubts about using fertilizer produced from human excrement in the field? Reason for Responses.

Reasons	Subcategories	Comments
Reasons for Yes	Unknown	I do not know; I do not see how it would be, and I do not know how to use it.
	Odour	The smell
	Positive	It is good
	Fertility	For fertility, it would have
	Insecurity	I do not feel secure.
	Function	For the function, it will have
	Unfamiliar	I do not know it
	Health Concerns	Because what we eat can produce diseases, it would bring diseases to the air.
	Bacteria	Because of the bacteria that might survive, it is disgusting(bacteria).
	Process	I want information; I do not know the process.
	Environmental Impact	It does not affect the planet or our family.
Reasons for No	Positive	It is good.
	Neutral or Indifferent	No

Question 18

Table K.20. Would you have any concerns or doubts about using fertilizer from animal manure in the field?

Answer choices	Responses (%) and Number of Participants
Yes	19.3%,17
No	80.7% 71

Table K.21. Would you have any concerns or doubts about using fertilizer from animal manure in the field? Reason for Responses.

Reasons	**Subcategories**	**Comments**
Reasons for Yes	Health Concerns	For my health, Because of the bacteria that might survive
	Odour	The smell
	Function	For the function
	Safety	It might not be safe.
	Cleanliness	That it will end up being clean
	Contamination	It is contaminated
	Natural	Everything is natural without chemicals.
	Consequence	Any consequence it might bring
	Production Process	In how it is produced
	Curiosity	I would like to know more.
Reasons for No	Neutral or Indifferent	No specific reasons were provided, indicating a neutral or indifferent stance.

Question 19

Table K.22. What would concern you about using fertilizer from human excrement?

Answer choices	**Responses (%) and Number of Participants**
Nothing	18.18%, 16
My health	71.59%,63
The smell	50.00%,44
I would not feel comfortable	38.64%,34
What people say	3.41%,3
The cost	7.95%,7
Other	7.95%,7

Question 20 -

Table K.23. What would concern you about using fertilizer produced from animal manure?

Answer choices	**Responses (%) and Number of Participants**
Nothing	36.36%, 32
My health	53.41%, 47
The smell	43.18%, 38
I would not feel comfortable	19.32%, 17
What people say	3.41%, 3
The cost	11.36%, 10
Other (Specify)	7.95%, 7

Question 21

Table K.24. Would you have any problem using gas for cooking produced from animal manure?

Answer choices	Responses (%) and Number of Participants
Yes	21.59%%,19
No	61.36% 54
I am not sure	17.05%,15

Table K.25. Would you have any problem using gas for cooking produced from animal manure? Reason for Responses.

Reasons	**Subcategories**	**Comments**
Reasons for Yes	General	Try it; it is disgusting and unhygienic because we need the infrastructure. It is disgusting
Reasons for No	Cleanliness	It is cleaner because it is vegetal and natural.
	Environmental	More ecological
	No Specific Reason	I do not know. Why not? I do not have animals; It would be more economical for none.
Reasons for Not Sure	Taste	It has bad taste
	Smell	It is because of the smell.
	Uncertainty	I have no comment on the consequences it may bring to my family and the planet because I do not know if it is harmful to health.

Question 22

Table K.26. Would you have any problem using gas for cooking produced from human excrement?

Answer choices	**Responses (%) and Number of Participants**
Yes	35.23%,31
No	40.91% 36
I am not sure	23.86%,21

Table K.27. Would you have any problem using gas for cooking produced from human excrement? Reason for Responses

Reason	**Subcategory**	**Comments**
Reasons for Yes	Health Concerns	It has many chemicals; I feel bad
	Odour	It is disgusting because of the smell.
	Uncertainty	I do not know, I do not know anything about the topic, and I do not know if it is safe.
	Cost	It cheap
	Contamination	The smell and contamination are caused by everything we consume.
	Dislike	I would not say I like it; It is disgusting.
	Explosiveness	Does it not explode?
	Taste	bad taste
	Unfamiliarity	not knowing what it will smell like, we need to know how it would be used
	Process	I do not know what the process would be like, like the smell and the process.
	Safety Concerns	Because of the consequences, I think the smell is harmful.
Reasons for No	No specific reasons were provided	Nothing, none.
Reasons for Not Sure	General Uncertainty	No comments.

Question 23

Table K.28. What would concern you about using gas for cooking produced from human waste?

Answer choice	**Responses (%) and Number of Participants**
Nothing	30.68%, 27
My health	55.68%, 49
The smell	40.91%, 36
I would feel uncomfortable	38.64%, 34
What people say	5.68%, 5
The cost	7.95%, 7
Other (Specify)	2.27%, 2

Question 24

Table K.29. Have you heard that the sun can generate electricity?

Answer choice	Responses (%) and Number of Participants
Yes	87.64%,78
No	12.35%, 11

Question 25

Table K.30. Would you have any problem using electricity produced from the sun?

Answer choice	Responses (%) and Number of Participants
Yes	3.41%, 3
No	94.32%, 83
Not sure	2.27%, 2

Table K.31. Would you have any problem using electricity produced by the sun? Reason for Responses

Reasons	Subcategories	Comments
Reasons for No	Usage	I use a solar heater.
	Impact	It does not affect me unless there is no sun or it is cloudy.
	Environmental benefits	More ecological
	Savings	It would save a lot
	Non-Usage	I do not use it
	Safety	If it does not affect us.
	Importance	I think it is essential.
Reasons for Yes	Uncertainty	I do not know

Question 26

Table K.32. What would concern you about using sun-generated electricity?

Answer choice	Responses (%) and Number of Participants
Nothing	76.14%, 67
My health	11.36%, 10
The smell	1.14%, 1
I would feel uncomfortable	3.41%, 3
What people say	0.00%, 0
The cost	10.23%, 9
Other (Specify)	7.95%, 7

Question 27

Table K.33. Do you know what bioenergy is (like biogas or biofuel)?

Answer choice	Responses (%) and Number of Participants
No	81.82%, 72
Yes	18.18%, 16

Question 28

Table K.34. Do you know what a biodigester is?

Answer choice	Responses (%) and Number of Participants
No	86.36%, 76
Yes, explain	13.64%, 12

Question 29

Table K.35. What are the main uses of electricity in your home?

Answer choice	Responses (%) and Number of Participants
Appliances	64.77% (57)
Pump	42.05% (37)
Television	73.86% (65)
Computers and electronic devices	47.73% (42)
Lights	78.41% (69)
Washing machine	73.86% (65)
Other (Specify)	5.68% (5)

Question 30

Table K.36. What do you use energy for at work?

Answer choice	Responses (%) and Number of Participants
Pump	18.18%, 16
Work tools	37.50%, 33
Work equipment (Refrigerator, oven, and mill)	47.73%, 42
Other (Specify)	25.00%, 22

Question 31

Table K.37. Have you experienced a blackout in your home in the last three months?

Answer choices	Responses (%) and Number of Participants
Yes	68.18%, 60
No	31.82%, 28

Question 32

Table K.38. Do you know the reason?

Answer choice	Responses (%) and Number of Participants
a. Problems with CFE (power grid)	45.45%, 40
b. Damage to the electrical cable at home	17.07%, 15
c. Other (Explain)	42.05%, 37

Question 33

Table K.39. What is the maximum time for the power to return after a blackout?

Categories	Comments
Common Duration	Many respondents mentioned that power typically returns within 24 hours, with several stating 'one day' or '24 hours.'
Short Durations	Some respondents experienced shorter blackout durations, ranging from 5 minutes to a few hours (e.g., 30 minutes, one hour, two hours).
Extended Durations	Several respondents reported extended blackout periods lasting up to several days. Some mentioned two days, three days, or even a week.
Variable Durations	Responses that depend on the occasion, sometimes hours, and vary from one to six hours indicate that the duration can be inconsistent and situation-dependent.

Question 34

Table K.40. Has your house been without direct water (from the tap) in the last three months?

Answer choices	Responses (%) and Number of Participants
Yes	61.36%, 54
No	38.64%, 34

Question 35

Table K.41. How long has your house been without water?

Answer choices	Responses (%) and Number of Participants
Few hours	27.58%, 24
Days	47.12%, 41
Unknown	9.19%, 8
0.5 Day	6.89%, 6
Various Hours	6.89%, 6
1 Day	1.15%, 1
Minutes	1.15%, 1

Question 36

Table K.42. In my house, I use LP gas (Butane) for cooking.

Answer choices	Responses (%) and Number of Participants
Always	86.36%, 76
Very frequently	9.09%, 8
Frequently	0.00%, 0
Occasionally	2.27%, 2
Rarely	1.14%, 1
Never	0.00%, 0
I do not know.	1.14%, 1

Question 37

Table K.43. In my house, I use firewood for cooking.

Answer choices	Responses (%) and Number of Participants
Always	3.41%, 3
Very frequently	5.68%, 5
Frequently	7.95%, 7
Occasionally	31.82%, 28
Rarely	22.73%, 20
Never	25.00%, 22
I do not know.	3.41%, 3

Question 38

Table K.44. Are you planning to emigrate to another state or country?

Answer choices	Responses (%) and Number of Participants
Yes	16.09%, 14
No	68.97%, 60
Not sure	14.94%, 13

Questionnaire 2

Question 1

Table K.45. Do you think the biodigester would help your community?

Answer choices	Responses (%) and Number of Participants
Yes	91.76%, 78
No	8.24%, 7

Question 2

Table K.46. What is the biggest problem with using the biodigester in your community?

Answer choices	**Responses (%) and Number of Participants**
None/No Issues	46.15%, 36
Animal Manure Collection	15.38%, 12
Availability of Manure	8.97%, 7
Cost	7.69%, 6
Odour	5.13%, 4
Community Involvement	7.69%, 6
Space Requirements	3.85%, 3
Knowledge and Information	3.85%, 3
Integration with Neighbours	1.28%, 1

Question 3

Table K.47. Name two benefits the biodigester would give your community.

Answer choices	**Responses (%) and Number of Participants**
Financial Savings	44.87%, 35
Environmental benefits	29.49%, 23
Gas Production	15.38%, 12
Fertilizer Production	10.26%, 8

Question 4

Table K.48. Do you think solar panels would benefit your community?

Answer choices	**Responses (%) and Number of Participants**
Yes.	96.47%, 82
No.	3.53%, 3

Question 5

Table K.49. Name two benefits solar panels would give your community.

Answer choices	**Responses (%) and Number of Participants**
Financial Savings	43.90%, 36
Environmental benefits	21.95%, 18
Community Benefits	13.41%, 11
Energy Independence	12.20%, 10
General Positive Statements	8.54%, 7

Question 9

Table K.50. How important do you think saving on your electricity bill is as a financial benefit?

Answer choices	Responses (%) and Number of Participants
Very important	76.47%, 65
Important	18.82%, 16
Moderately important	1.18%, 1
Of little importance	0.00%, 0
Insignificant	0.00%, 0
I do not know	3.53%, 3

Question 10

Table K.51. How important do you consider the savings on the gas bill as a financial benefit?

Answer choices	Responses (%) and Number of Participants
Very important	74.12%, 63
Important	20.00%, 17
Moderately important	1.18%, 1
Of little importance	1.18%, 1
Insignificant	0.00%, 0
I do not know	3.53%, 3

Question 11

Table K.52. This project will generate financial gains (solar panels or biodigester). What should that money be spent on?

Categories	**Comments**	**Responses (%) and Number of Participants**
Education	In schools, to improve our children's education, for schools, and on the streets.	6.0%,3
Infrastructure	Streets and pavements, In the well, streets, in what is necessary, like streets, in paving streets, in the community, repairs, in community needs, to improve the streets.	18.0%,9
Community Benefits	Improvements for the community, Gardens in the community, in the park, In the community needs	39.0%,20
Environment	To take care of the environment, make improvements for the environment, install solar panels, and build a biodigester.	8.0%,4
Basic Needs	In food, clothing, medicines, the pantry, groceries, and health for my family.	14.0%,7
Not Specified		15.0%,8

Question 12

Table K.53. How important do you consider the community park to benefit the community?

Answer choices	Responses (%) and Number of Participants
Very important	64.71%, 55
Important	28.24%, 24
Moderately important	3.53%, 3
Of little importance	0.00%, 0
Insignificant	0.00%, 0
I do not know	3.53%, 3

Question 13

Table K.54. How important do you consider improving school facilities to benefit the community?

Answer choices	Responses (%) and Number of Participants
Very important	75.29%, 64
Important	22.35%, 19
Moderately important	1.18%, 1
Of little importance	0.00%, 0
Insignificant	0.00%, 0
I do not know	1.18%, 1

Question 14

Table K.55. Do you think your neighbours would have problems using electrical energy from human feces?

Answer choices	Responses (%) and Number of Participants
Yes	21.18%, 18
I am not sure	58.82%, 50
No. Explain	20.00%, 17

Question 15

Table K.56. Do you think your neighbours would have problems using electricity from animal manure?

Answer choices	Responses (%) and Number of Participants
Yes	10.59%,9
I am not sure	63.53%, 54
No. Explicit	25.88%, 22

Question 16

Table K.57. Do you think your neighbours would have any concerns or doubts about using fertilizers from human feces in their fields?

Answer choices	Responses (%) and Number of Participants
No	69.41%, 59
Yes. Explain	30.59%, 26

Question 17

Table K.58. Do you think your neighbours would have any concerns or doubts about using animal manure fertilizers in their fields?

Answer choices	Responses (%) and Number of Participants
No	81.18%, 69
Yes. Explain	18.82%, 16

Question 18

Table K.59. What would you be most concerned about using fertilizers from human feces?

Answer choices	Responses (%) and Number of Participants
Nothing	34.12%, 29
My health	47.06%, 40
The smell	8.24%, 7
I would not feel right	1.18%, 1
What People Are Saying	1.18%, 1
Other. Explain	8.24%, 7

Question 19

Table K.60. What would you be concerned about using animal manure (biol) fertilizers?

Answer choices	**Responses (%) and Number of Participants**
Nothing	51.76%, 44
My health	15.29%, 13
The smell	24.71%, 21
I would not feel right	3.53%, 3
What People Are Saying	1.18%, 1
Other	3.53%, 3

Question 20

Table K.61. Do you think your neighbours would have trouble using cooking gas made from animal manure?

Answer choices	Responses (%) and Number of Participants
No	52.94%, 45
I am not sure	41.18%, 35
Yes	5.88%, 5

Question 21

Table K.62. Do you think your neighbours would have problems using cooking gas from human feces?

Answer choices	Responses (%) and Number of Participants
No	32.94%, 28
I am not sure	47.06%, 40
Yes	20.00%, 17

Question 22

Table K.63. What would you be most concerned about using cooking gas produced from human feces?

Answer choices	Responses (%) and Number of Participants
Nothing	32.94%, 28
My health	32.94%, 28
The smell	16.47%, 14
I would not feel right	8.24%, 7
What People Are Saying	0.00%, 0
Other (Explain)	9.41%, 8

Question 23

Table K.64. Would you mind using the electrical energy produced by the sun?

Answer choices	Responses (%) and Number of Participants
No	94.12%, 80
I am not sure	4.71%, 4
Yes. Why?	1.18%, 1

Question 26

Table K.65. Do you think your neighbours would use fertilizer on their crops produced from human feces?

Answer choices	Responses (%) and Number of Participants
Yes	56.47%, 48
No	43.53%, 37

Question 28

Table K.66. Would you buy cooking gas obtained from human feces?

Answer choices	Responses (%) and Number of Participants
Yes	60.00%, 51
No	40.00%, 34

Question 29

Table K.67. Energy production (cooking gas/solar panels) is one of the benefits of the biodigester. How do you think this benefit should be enjoyed?

Answer choices	Responses (%) and Number of Participants
As a discount on your electricity bill	43.53%, 37
In some projects for the community	29.41%, 25
In a Community Savings Fund	21.18%, 18
Other (Explain)	5.88%, 5

Question 30

Table K.68. Seeking the benefit of the community: What do you think is convenient to invest the money raised from the project? (give three examples)

Category	Comments	(%) and Number of Participants
Infrastructure	fix streets, streets, paving, to pave, improve streets, improve roads, drainage.	26.29%,56
Environmental Projects	Garden, for trees, biodigester, plant trees, green areas, clean the environment.	20.66%,44
Community Projects	expansion of the drainage network for community benefits, biodigester, community works, and benefits for the community.	19.25%,41
Education	Computers are needed in schools, better schools.	15.02%,32
Family	To eat would cost less, food for the family, energy savings, improved living conditions, basic needs, and groceries.	8.92%,19
Not Specified	I do not know	5.63%,12
Health	Medicine, health, cleaning, medicine, health centers, improving the health system.	4.23%, 9

Question 32

Table K.69. As explained, would you be interested in participating in the project?

Answer choices	Responses (%) and Number of Participants
Yes	78.82%, 67
No	5.88%, 5
I do not know	15.29%, 13

Question 33

Table K.70. Would you join us and other community members in working on the project?

Answer choices	Responses (%) and Number of Participants
Yes	85.88%, 73
No	7.06%, 6
I prefer not to answer	7.06%, 6

Question 34

Table K.71. How easy do you think it will be for community members to join the project?

Answer choices	Responses (%) and Number of Participants
Very easy	20.00%, 17
Pretty easy	11.76%, 10
Moderately easy	21.18%, 18
Difficult	11.76%, 10
Easy	17.65%, 15
I do not know	17.65%, 15

Question 35

Table K.72. The biodigester will require maintenance to obtain all these benefits. Who do you think should be responsible for maintenance?

Answer choices	Responses (%) and Number of Participants
An employee from outside the community	16.47%, 14
An employee who belongs to the community	49.41%, 42
A volunteer who belongs to the community	30.59%, 26
Other (Explain)	3.53%, 3

Question 36

Table K.73. If you were the volunteer, how many hours per week would you be willing to do maintenance?

Answer choices	Responses (%) and Number of Participants
No	20.00%, 17
1	23.53%, 20
2	32.94%, 28
3	14.12%, 12
4	9.41%, 8

Question 37

Table K.74. If hiring anyone for maintenance was unnecessary, this would generate financial savings. Where do you think it should be used?

Answer choices	Responses (%) and Number of Participants
Among families as additional income.	34.12%, 29
In infrastructure for the community	61.18%, 52
Other (Explain)	4.71%, 4

Question 38

Table K.75. What is your gender?

Answer choices	Responses (%) and Number of Participants
Female	62.35%, 53
Male	21.18%, 18
Not answered	16.47%, 14

Question 39

Table K.76. How old are you?

Answer choices	Responses (%) and Number of Participants
14- 17	24.71%, 21
18-21	7.06%,6
22-25	4.71%, 4
26-29	4.71%, 4
30-35	15.29%, 13
36-41	12.94%, 11
42-49	9.41%, 8
50-54	7.06%, 6
55-59	7.06%, 6
60-64	2.35%, 2
65-69	1.18%, 1
70-74	0.00%,0
75-79	1.18%,1
80 and up	0.00%, 0
I prefer not to say it	2.35%, 2

Question 40

Table K.77. What is your marital status?

Answer choices	Responses (%) and Number of Participants
Bachelor	40.00%, 34
Married	49.41%, 42
Widow (a)	3.53%,3
Divorced	4.71%, 4
Separate	2.35%, 2

Question 41

Table K.78. What is your main occupation?

Answer choices	Responses (%) and Number of Participants
Housewife	41.18%, 35
Employee	23.53%, 20
Student	21.18%, 18
Farmer/Rancher	2.35%,2
I prefer not to say it	3.53%,3
Other (Specify)	8.24%,7

Table K.79. do you have any other jobs besides your primary occupation?

Answer choices	Responses (%) and Number of Participants
No	49.41%, 42
Housewife	27.06%, 23
Worker	18.82%, 16
Student	4.71%, 4
Farmer/Rancher	0.00%, 0

Question 43

Table K.80. What is your highest degree of study?

Answer choices	Responses (%) and Number of Participants
I did not study.	3.53%, 3
Primary.	20.00%, 17
Middle school(secundaria).	28.24%, 24
High school	36.47%, 31
Technical career.	0.00%, 0
Degree.	5.88%, 5
I prefer not to say it.	5.88%, 5

Question 44

Table K.81. How much is your family's income per week?

Answer choices	Responses (%) and Number of Participants
500-1000 pesos	41.18%, 35
1000-1500 pesos	22.35%, 19
1500-2000 Pesos	12.94%, 11
2000-2500 pesos	2.35%, 2
2500-3000 pesos	7.06%, 6
3000-3500 pesos	14.12%, 12

Results from Questionnaire 3

Question 1

Table K.82. Usually, what do you do with the manure from your livestock?

Answer Choices	**Responses (%) and Number of Participants**
Use it as fertilizer	75.00%, 9
Sell it	0.00%, 0
Leave it by the roadside for someone else to collect	0.00%, 0
Other (Explain)	25.00%, 3

Question 2

Table K.83. How many heads of cattle do you have? Describe what you have

Participant	**Responses**
1	6 ewes
2	2 ewes
3	17 ewes, 2 mares, 1 mule
4	10 sheep
5	10 ewes
6	14 goats
7	7 goats
8	10 cows
9	11 unspecified
10	2 cows and 2 goats
11	6 goats
12	5 sheep

Table K.84. How many heads of cattle do you have? Percentage.

Animal Type	Percentage (%)
Ewes	33.91
Sheep	14.53
Goats	28.10
Cows	10.85
Mares	0.98
Mule	0.98
Unspecified	10.66

Question 3

Table K.85. How many times a week do you take them out to graze?

Participant	Responses
1	2 times per week
2	once or twice a week
3	Currently, they are not taken out; there is no pasture. Buy pasture
4	Any
5	Currently, they are not taken out; there is no pasture. Buy pasture
6	I do not take them out.
7	I do not take them out.
8	daily, 4-5 hours
9	Five
10	daily
11	once a week
12	I do not take them out.

Question 4

Table K.86. Would you like to participate in giving your livestock manure to the biodigester project?

Answer Choices	Responses (%) and Number of Participants
Yes	91.67%, 11
No	8.33%, 1
Do not know	0.00%, 0

Question 5

Table K.87. How often can you contribute livestock manure?

Answer Choices	Responses (%) and Number of Participants
Daily	25.00%, 3
3 to 5 days a week	16.67%, 2
Once a week	58.33%, 7

Question 6

Table K.88. How many kilograms of manure could you contribute to the project?

Participant	kg
1	50
2	0
3	20 to 30
4	60
5	20
6	15
7	20
8	100
9	200
10	300
11	50
12	40

Table K.89. Can you transport the manure to the biodigester?

Answer Choices	Responses (%) and Number of Participants
Yes	50.00%, 6
Depends on the distance	33.33%, 4
No. I need it to be collected	16.67%, 2

Question 8

Table K.90. Would you pay to have your animal pen cleaned every two days?

Answer Choices	Responses (%) and Number of Participants
Yes	0.00%, 0
No	91.67%, 11
Do not know	8.33%, 1

Question 9

Table K.91. If you had to pay for pen cleaning every third day, how much would you pay?

Answer Choices	Responses (%) and Number of Participants
I would not pay	100.00%, 12
Less than 20 pesos	0.00%, 0
20 pesos	0.00%, 0
30 pesos	0.00%, 0
40 pesos	0.00%, 0

Question 10

Table K.92. What benefit would you like to receive in exchange for your contribution?

Answer Choices	Responses (%) and Number of Participants
Money	25.00%, 3
Fertilizer for your crops	66.67%, 8
Other (Explain)	8.33%, 1

Question 11

Table K.93. Identify a problem in your community where the project can help with the income it generates.

Answer Choices	Responses (%) and Number of Participants
Deforestation	7.69%, 1
Combat delinquency	0.00%, 0
Infrastructure	15.38%, 2
Lack of water	46.15%, 6
Garbage problems	30.76%, 4
Other (Explain)	0.00%, 0

Question 12

Table K.94. What is your gender?

Participant	Responses
1	male
2	male
3	male
4	male
5	male
6	female
7	male
8	male
9	male
10	male
11	female
12	female

Question 13

Table K.95. What is your age?

Answer Choices	Responses (%) and Number of Participants
18-24	0.00%, 0
25-29	0.00%, 0
30-34	0.00%, 0
35-39	25.00%, 3
40-44	16.67%, 2
44-49	16.67%, 2
50-54	8.33%, 1
55-59	25.00%, 3
60-64	0.00%, 0
65-69	0.00%, 0
70-74	8.33%, 1
75-79	0.00%, 0
Over 80	0.00%, 0
I prefer not to say	0.00%, 0

Question 14

Table K.96. What is your marital status?

Answer Choices	Responses (%) and Number of Participants
Single	0.00%, 0
Married	91.67%, 11
Widowed	0.00%, 0
Divorced	8.33%, 1
Separated	0.00%, 0

Question 15

Table K.97. What is your occupation?

Participant	Responses
1	Farmer
2	Work at the dam
3	Security guard
4	Field, merchant
5	Unanswered
6	Housewife
7	Farmer
8	Livestock
9	Farmer
10	Unanswered
11	Housewife
12	Housewife

Question 16

Table K.98. What is your level of education?

Answer Choices	Responses (%) and Number of Participants
None	8.33%, 1
Primary school	25.00%, 3
Secondary school	50.00%, 6
High school	16.67%, 2
College degree	0.00%, 0
I prefer not to say	0.00%, 0
Other (Specify)	0.00%, 0