Chapter

A Case Study for Economic Viability of Biogas Production from Municipal Solid Waste in the South of Chile

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Abstract

This research evaluated the technical and economic feasibility of a biogas plant in the south of Chile to generate energy (WtE) for the plant's own consumption, energy for sale to the country's electricity grid and produce biofertilizer from municipal solid waste (MSW). In the town of Panguipulli, 26 tons of solid waste are produced daily, of which 12 tons correspond to household organic waste. These arrive directly to a landfill, wasting their potential to generate products and energy. To study the economic feasibility, an analysis was carried out on the investment, costs and income that make up the cash flow of the project evaluated at 15 years. The results gave an NPV of 214.099.637 CLP and an IRR of 15% at a real discount rate of 10%, with a payback period of 6 years. The research concluded that it is feasible to design a biogas plant that works from household organic waste in Panguipulli. This will contribute to the mitigation of climate change and will promote circular economy actions and the sustainable management of MSW in the south of Chile.

Keywords: economic viability, biogas, municipal solid waste, Chile, waste to energy

1. Introduction

This chapter points out the problems present in cities as a result of the excessive growth of waste production. This negative externality must be managed through a management system, which not only accumulates it in a sanitary landfill, but also generates social and economic benefits. From this angle, Doussoulin highlights the important role of the state in supporting the transition from a linear production system to a circular one, urban waste is reused, extending its useful life and reducing negative externalities on the biosphere [1]. One of the key sectors in the generation of urban waste and its recycling is the construction sector in Latin American cities [2, 3].

Currently, there are several options to reuse urban waste. For example, composting, recycling and biomass that can be transformed into biogas, the latter topic will be addressed in the next investigation [2]. It will be necessary to understand some concepts about biogas. Rivas defines biogas production from household organic waste as a natural process, without oxygen carried out by microorganisms, this involves the fermentation of organic materials to obtain the biogas [3]. Furthermore, biodigesters are systems designed to optimize the production of biogas, obtaining clean and low-cost energy [4]. As some authors have stated; gas extraction from waste, responds to the need to close the circle, returning natural resources to their origin [5]. The technological, legal and economic challenges and the opportunities for improvement in the well-being of developing countries have been studied and pointed out by various authors [6, 7]. The demonstration issues in major countries can be illustrated as follows (see **Table 1**).

Table 1 shows that the extraction of biogas from garbage is a relevant issue in South American countries. This is also emphasized by various Chilean authors on issues such as: the design of networks of biogas [26], environmental sustainability [27] and municipal waste management [28]. Therefore, this chapter continues and deepens these works taking advantage of the challenges and opportunities of biogas production. Thus, this study aims to study the feasibility of profitably investing in a biogas generating plant in the commune of Panguipulli from household organic waste. This will mean a crucial advance towards the reduction of the waste that reaches the landfill, therefore less environmental pollution, promotion of unconventional energies and direct solutions to citizens' problems by having a low-cost, good-quality product available. This research is mainly related to the search to alleviate energy poverty that currently exists, reducing economic barriers and in this way making a product as essential as gas more accessible to the public, whether it is used directly as fuel or electricity is generated from it [29]. This is why it is intended in the following research, to discover if it is feasible to invest in a generating plant of biogas in the Panguipulli commune by calculating the costs of the installation of a large-scale plant that meets the needs of the commune, as well as a calculation of the costs of the materials involved in the entire generation process of biogas, and finally to discover if the investment is recovered and if so, in how long a time.

The importance of this study concerns: first, the results will provide an important economic and time saving, since they will be of great help in upcoming projects related to landfill waste management policies and the generation of renewable energies in Chile. An attractive investment project in the medium and long term for

Country	Scholar	Issues
Belgium	[8, 9]	Anaerobic reactor for the biogas production from the pineapple and sweet sorghum
France	[10, 11]	Anaerobic reactor for the biogas production from the feedstock
UK	[12, 13]	Transport and energy crops fodder beet, forage maize, sugar beet and ryegrass
Argentina	[14, 15]	Biogas potential from MSW and aquatic plants
Brazil	[16, 17]	Biogas potential from MSW
USA	[18, 19]	Chemicals industry
South Africa	[20, 21]	Agricultural crops biogas
Canada	[22, 23]	Circular economy
China	[24, 25]	Household biogas use in the rural area

Data Source: [10–27].

Table 1.
Main demonstration issues related to biogas.

the entity that has the financial resources to carry it out. Second, this research will also carry out a study of the composition and volume of a substrate to be used in this specific case, investment analysis, costs and income that will make up a cash flow of a project evaluated at 15 years. In addition, some economic indicators are calculated to evaluate the viability of the project, these are: net present value (NPV), Internal rate of return (IRR) and Payback. Third, there is not much research on biogas plants in southern Chile. These biogas plants operate on a very small scale, the result of which is that there is no literature related to this geographical area.

This study explores the gap in the literature by answering whether the construction of a biogas plant in the commune of Panguipulli is economically profitable? The added value of this proposal is that it proposes an alternative use of the biogas applicable to the national reality and specifically to the Panguipulli commune, reducing negative environmental externalities as a result of their mismanagement emissions. Indeed, there is a lack of knowledge of the energetic potentiality of the biogas, for which an energetic waste arises and economical from the biogas emanating from the landfill. All of the above allow biogas generated in the sanitary landfill to not be managed correctly, causing the release of greenhouse gases such as CH_4 and CO_2 to a greater extent, which contribute to global warming, in addition to the contamination of the land and underground water.

Next, a compilation of information related to the biogas generation, similar studies, history of waste management and other data that the author considered relevant, all this was consulted in materials of authors with track records.

The chapter is structured as follows: Section 2 outlines a background of biogas production. Section 3 identifies the main results. Section 4 concludes and proposes future research direction.

2. Background

A large amount of waste is generated uncontrollably every day. From an environmental perspective, it is good to reduce the amount of waste that ends up to landfills, a part of this garbage being household organic waste that is usually thrown away along with everything else. In some parts of the world, the great potential that these projects have has been understood and projects have been created to reduce pollution, promote non-conventional renewable energies and generate a good quality product that allows an economic profit to be obtained. In other words, Parra refers to the fact that food residues (RA) have a high potential for reuse through biological processes such as anaerobic digestion (AD), especially due to their high content of biodegradable organic matter [30].

As a result of the decomposition of this organic material carried out by microorganisms, biogas is produced. A study by Gamma engineers defines it as a combustible gas that is generated in natural environments or specific devices, by the biodegradation reactions of organic matter, through the action of microorganisms in the absence of oxygen, that is, under anaerobic conditions [31]. Therefore, to optimize biogas production, this process is carried out in biodigesters in order to provide the right conditions for biogas extraction. In addition, as a by-product of this process, you can obtain bio-fertilizer [32].

The need to manage urban waste dates back to the time of the Roman Empire. They already had an environmental conscience, they worried about where their vessels and ceramics would go, and from there comes recycling. They recovered them to make other containers, used as fertilizer in agriculture or even as material for construction.

Some of the first authors to refer to biogas production were Sanghi and colleagues in 1977 [33]. This chapter pointed out the benefits of an anaerobic digester, and its generating potential for energy, where they saw it as an alternative to reduce the money invested in oil imports.

In Chile, there is great potential to generate energy with biogas from waste, not only in landfills but also in agriculture, forestry, the food industry and salmon farming. According to Ortiz, until 2017, there were 25 biodigesters nationwide, of which 10 are in the operating phase located in the Los Lagos region, the other biodigesters were in the project and start-up phase. This shows that the power generation potential has not been fully exploited [34].

When collecting information on business models applied in different parts of the world, we can find that there are five producing countries that have been able to make this product, these are Germany, Spain, Brazil, Canada and Sweden. A report from the ministry of energy of Chile mentions factors that they have in common, that is, they receive a state boost in the form of investment subsidies. In Germany, Spain and Canada the projects of biogas that generate energy for sale to the grid have a guaranteed rate. In Sweden, the use of biogas as a vehicle fuel has also been given impetus. Setting it as tax-free fuel and subsidizing the purchase of vehicles that work with biomethane [31].

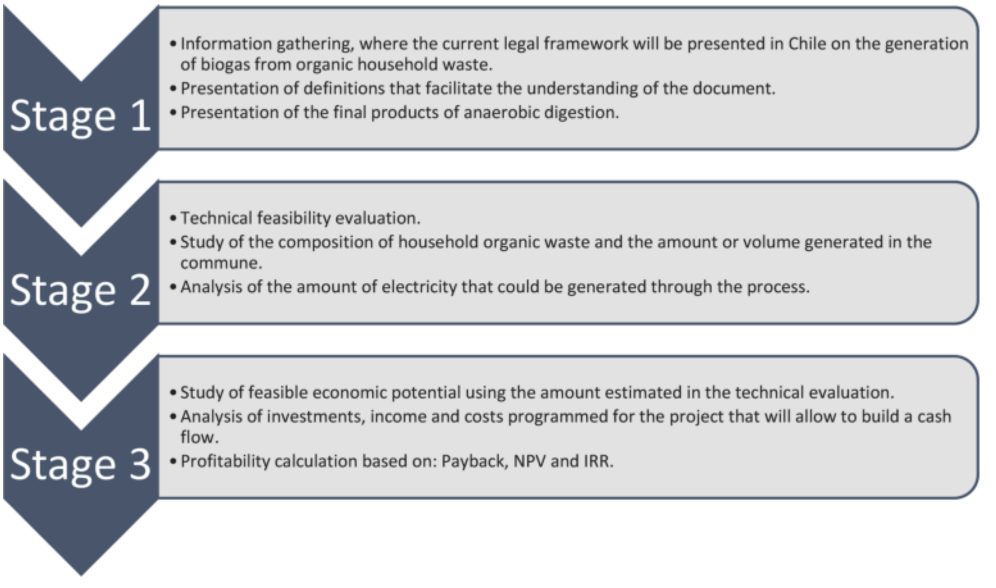
It is important to mention that the process of obtaining gas from garbage is commercially viable [35]. Regarding the Chilean national regulation, there are minimum requirements for the sale of energy to the central interconnected network, which suggests that generating electricity from biogas may be a possibility of business. Jaramillo & Matthews mention that in addition to an economic benefit there is a social benefit for this type of project [36]. This allows for meeting the needs of the community, it is friendly to the environment since it does not increase the amount of carbon dioxide in the atmosphere and it constitutes a great sustainable alternative by promoting greater awareness about a more balanced relationship with nature.

A case study in Mexico makes an estimate of waste per capita of Michoacán of waste with its specific percentages for each type of material, estimation of the biogas production through the Mexican biogas model version 2.0, developed by SCS Engineers under agreement with the LMOP program of the Environmental Protection Agency of the United States (US EPA) [37]. The model generates biogas production and capture projections depending on waste management and arrangement of the sanitary landfill, in order to carry out short-term feasibility studies, medium and long term of this type of project. The description of the scenarios of this study will guide the modeling of biogas generation to be done in a larger proportion [38].

This project proved to be technically and economically feasible, the data that were required are very similar to those that will be needed in this investigation, for example, the costs of the entire project, amount of tons available at the end of the project, benefits of each ton of organic waste. The results summarized by Vera indicate that the benefit obtained from saving electricity is compared with the cost of a study that includes three important aspects: the investment cost, operation and maintenance [39]. This study shows that the scenarios studied are above the cost of a sanitary landfill, which indicates that a project with these characteristics is prefeasibility even if the biogas capture efficiency is the lowest (40%) [38].

3. Methods

As mentioned in the preceding sections, this research analyses an investment project for the creation of a biogas plant, from household organic waste in the commune of Panguipulli. This research arises from identifying a waste of the energy potential of waste in the commune. The general aspects of the project include the following stages.



It is important to mention that the use of the previously exposed methodology allows an analysis of the technical requirements of a biogas plant, in addition, projected income will be considered and expenses to measure its potential returns.

3.1 Stage 1

3.1.1 Legal framework

All projects must comply with a minimum regulatory framework for their legal operation:

1. The Supreme Decree of Chile No. 119 of the year 2016 generated by the Ministry of Energy is related to the regulation at the construction and operational level. This decree seeks to ensure safety [40].

2. Act 20.339 of the Ministry of Mining of 1978 requires that biogas plants be registered in the electricity and fuels [41].

3. Decree 10: Regulation of boilers, autoclaves and equipment that use steam water. This decree establishes the requirements for boilers and accessories related to combustion [42].

4. Act 20.571: This law regulates the operation of electrical generation equipment. They work on the basis of non-conventional renewable energies [43].

5. Act 20.698: Promotes the expansion of the energy matrix, through non-conventional renewables sources [44].

3.1.2 End products of anaerobic digestion

From anaerobic digestion, final products are obtained such as biogas with energy-generating potential, as well as a stable biosolid that is used to improve the soil (biofertilizer or biofertilizers). This is an organic product with a high quantity of nutrients, it is not polluting and does not have pathogenic microorganisms, and finally a mixture of water and solids, the latter are obtained from the anaerobic decomposition of the substratum.

3.2 Stage 2

3.2.1 Biomass availability

In 2019 a characterization of the composition of the MSW was carried out, this showed that the total waste generated in Panguipulli is 9361 tons per year. **Figure 1** shows the MSW generated each month in 2019.

A total of 46% of the 9361 tons of household solid waste generated in Panguipulli, corresponds to household organic waste. A graph showing the composition of MSWs is shown below. According to this information, we can conclude that 4,306,060 kilograms per year of organic waste are generated domiciliary, which is equivalent to 11,961 kilograms per day.

It is suggested that organic waste be separated in homes, at the moment in which they are generated, for this the cooperation of the population of Panguipulli is needed. In this process, conscious education on the separation of waste is of vital importance in order to have biogas according to expectations. In addition, this will drive a culture towards the sustainable management of household organic waste in the commune.

Given the current pandemic situation caused by COVID-19, it will be necessary to have safeguards in the handling of organic waste [45]. This is why some authors recommend taking measures for the adequate extraction of organic waste to seek the protection of workers who are part of the collection and transport of the substrate, reducing the possibility of being infected during their workday.

3.2.1.1 Plant

Plants can produce different amounts of biogas depending on the substrate used. In this study, for all calculations, it is taken into account that the substrate is waste of organic household products, which has a biogas production capacity of 50 m^3 per ton, this substrate is among the most profitable.

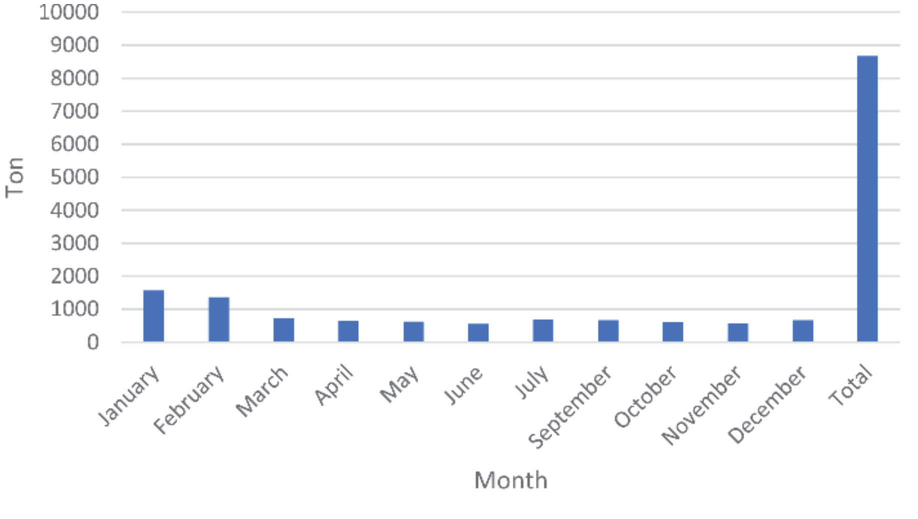


Figure 1.
Solid waste generated in 2019 in Panguipulli, Chile. Source: Department of Cleaning and Decoration of Panguipulli.

3.2.1.2 Plant operation

The biodigester generates methane from household organic waste. When methane begins to be generated, it will flow naturally to the capture point from the biodigester, from there, the electricity generator is fed, which is an engine optimized for the generation of electricity, using methane as fuel. The motor is powered by a gas pump and has a gas meter to monitor consumption.

3.2.1.3 Climatic factors

In order to implement this project, it will be important to consider climatic factors of the sector where the plant will operate, because the average climate in Panguipulli during the course of the year is between 3°C and 23°C. It may be necessary to implement a heated bioreactor and have proper insulation, this can increase some costs, since as the temperature of the biodigester increases, the speed of the growth of microorganisms increases, therefore, accelerating the digestion process obtaining a high content of methane in the biogas and conclusion obtaining profitable results.

3.2.1.4 Holding time

To generate the degradation process of organic waste or substrates time must pass, which depends directly on the temperature of the sector. For the calculations, the retention time used in biogas plants in the Los Rios Region will be taken as a reference where its substrate is also household organic waste.

Assuming its load is daily, the retention time will determine when the volume of charge needed to feed the digester is required. It is proposed to work with retention times of between 40 and 50 days and with daily loads of 10 kg per cubic meter of the digester.

3.2.1.5 Biogas generation potential estimate

The yield can be estimated according to the capacity of the biogas plant, these yield can be affected by factors such as retention time, temperature and agitation of the substrate, among others.

Table 2 shows total returns; the information used in its generation was: 1 ton is equivalent to 50 m^3 of biogas per day, 1 m^3 of biogas can generate 1.8 kilowatt-hour (kWh) per day, which delivers electrical power to the generator of 50 kW.

In addition, it is necessary to clarify that by the multiplication of the total biogas of each cubic meter per unit of KWh, the total kw per day of electrical energy production is obtained. **Table 2** with its data is shown below.

	Tons	Unit	Total biogas	Total kw/day
Biogas production per day	11,961 ton	50 m^3	598.05 m^3	
Electric power production		1.8 kwe	598.05 m^3	1076.49
Power electrical energy of the generator		50 kw		

Source: The authors.

Table 2.
Total yields from the listed biogas plant.

3.2.1.6 Ground

The land should be a flat surface, ideally, it has a sewer, to facilitate maintenance and be able to channel liquid elimination, if not, it will require trucks, and clean pits, which would increase maintenance costs. Furthermore, it is necessary that there is the availability of water. It is very important that the plant is exposed to the sun, there should not be a mound nearby to shade it. There must be good access for the trucks that will carry the raw material to enter without a problem.

3.2.1.7 Generating potential of biofertilizer

Among the by-products generated by the biogas plant, is the solid bio stable (soil improver) mentioned above in the scheme of the process of anaerobic digestion, this product can be used as a biofertilizer for soils, as it has nutrients such as potassium, phosphorus, nitrogen among others, which help to recover minerals lost in crops [46].

3.3 Stage 3: economic valuation

This section describes the aspects of the cash flow elaborated, in detail. Using the cash flow, economic indicators were obtained that allow evaluation of the profitability of the project. The calculations are presented in Appendix 1, with their respective NPV, IRR and Payback. These tools are the most suitable in this investigation as it allows the calculation of the time in which the initial investment will be recovered to be made more precise.

3.3.1 Income from the sale of electricity

It is one of the main incomes, which corresponds to 60% of the energy produced, it will be injected into the distribution network that under Law 20,571 has entered into force since 2014. For the calculations, we express prices and costs in CLP, 830 CLP is equivalent to 1 US dollar. A price of 385 CLP/kW was estimated, in addition the plant has an electric power of the generator of 50 kW, which generates 31,200 kW-month, the plant will produce electricity 24 hours a day for 6 days a week, taking a total of 4 days a month for maintenance. The income per sale will be constant over time. The above delivers a total annual income of 86.486.400 CLP. This information was collected from the data historical prices of the node near Panguipulli [47].

3.3.2 Income from energy savings in self-consumption

Energy generated by the biogas plant allows it to pay for the monthly energy supply which corresponds to 40% of all electrical energy produced. For this, the amount of kWh saved annually was valued by installing the biogas plant and the economic savings incurred were estimated. Therefore, an annual saving in electrical energy of 57.657.600 CLP is obtained.

3.3.3 Income from sale of biofertilizer

It was neither possible to find the value of the fertilizers that are used in the market nor the sale value of biofertilizers generated by biogas plants, since these depend on the chemical compositions. Therefore, to determine in some way the income of the biofertilizer, the price for sale at 44.8 CLP per kg was used and the percentage of recovery of organic matter for the generation of biofertilizer of 30% with respect to the initial organic matter. These data were recovered from a study of a biogas plant using grape marc as substrate [46]. Income from the sale of biofertilizer is equal to 58.060.800 CLP annually and will remain constant over time. The costs associated with this project are investment costs, operating and maintenance costs and costs for investments in intangibles.

3.3.4 Investment costs

It can be seen in the following table that the total cost of the investment required by the biogas plant amounts to 540.000.000 CLP (810 CLP are approximately 1 US dollar). The estimation percentages of the factors influencing the project were taken from Garay García thesis (see **Table 3**) [48].

3.3.5 Operation and maintenance costs

These costs are associated with the substrate (since currently the substrate is not used in anything, it does not have a cost or price), maintenance, waste disposal, costs of operating inputs and personnel costs. Total operating costs amount to 53.824.457 CLP yearly.

Regarding the personnel requirements, it is considered for the calculations that it is necessary to work with five people for the operation of the plant, where two people are technicians and work full-time and the others are full-time assistants. Estimates of personnel cost are 27.720.000 CLP per year.

Regarding the costs of inputs, water for the tributary of the digester is necessary, for the calculations of water used for loads of the tributaries, it is estimated 714.457 CLP yearly [49].

Another cost to consider is the maintenance and repairs of the equipment, this will be calculated based on percentages of the total investment cost. Total maintenance costs are equivalent to 25.390.000 CLP per year (see **Table 4**) [48].

3.3.6 Cost of investment in intangibles

This cost includes patents to function in a legal form, contracts, insurance for damage to equipment or motors, pumps, agitators, among others. In addition, it is recommended to take out insurance in case of earthquakes or other situations that may damage the investment. The cost associated with intangibles varies between 0.8% and 1% of total investments [46]. The total investment amounts to 540.000.000 CLP and must be considered in year 0.

Biodigester and cogeneration engine	270.000.000
Installation (30%)	81.000.000
Engineering (15%)	40.500.000
Start-up (15%)	40.500.000
Civil works (10%)	27.000.000
Electrical equipment, pipes and insulating materials (15%)	40.500.000
Contingencies (15%)	40.500.000
Net investment cost	**540.000.000**
Source: [47].	

Table 3.
Net investment cost in CLP.

Civil works (1%)	2.170.000
Equipment (4%)	1.620.000
Biodigester and cogenerator (8%)	21.600.000
Total cost of maintenance	25.390.000
Source: [47].	

Table 4.
Total cost of maintenance in CLP.

3.3.7 Land rental

Considering that this project could be executed by a municipality, as well as a private company, an estimated market rental value for urbanized land in the surroundings of the city of Panguipulli is equivalent to 3.600.000 CLP per year. The value is constant over time and is exempt from tax in accordance with the provisions of Exempt Resolution No. 300, of 1970, revalidated in accordance with instructions contained in Decree No. 111 of 1975 of Chile [50].

Year	Biodigester and cogeneration engine 270.000.000	Civil works 27.000.000	Equipment 40.500.000	Intangible 5.400.000	Total depreciation
0					-
1	27.000.000	1.350.000	4.050.000	1.800.000	34.200.000
2	7.000.000	.350.000	4.050.000	1.800.000	34.200.000
3	27.000.000	1.350.000	4.050.000	1.800.000	34.200.000
4	27.000.000	1.350.000	4.050.000		32.400.000
5	27.000.000	1.350.000	4.050.000		32.400.000
6	27.000.000	1.350.000	4.050.000		32.400.000
7	27.000.000	1.350.000	4.050.000		32.400.000
8	27.000.000	1.350.000	4.050.000		32.400.000
9	27.000.000	1.350.000	4.050.000		32.400.000
10	27.000.000	1.350.000	4.050.000		32.400.000
11		1.350.000			1.350.000
12		1.350.000			1.350.000
13		1.350.000			1.350.000
14		1.350.000			1.350.000
15		1.350.000			1.350.000
16		1.350.000			1.350.000
17		1.350.000			1.350.000
18		1.350.000			1.350.000
19		1.350.000			1.350.000
20		1.350.000			1.350.000
Source: [47].					

Table 5.
Depreciation per asset individually in CLP.

3.3.8 Working capital

The project will generate income from its start-up by the sale of electrical energy and biofertilizer, a working capital will be estimated that allows it to cover the first 3 months of operation, this includes rent, and operating cost and maintenance. The working capital is equivalent to 163.456.113 CLP annually.

3.3.9 Depreciation

Depreciation corresponds to the decrease in the value of assets due to their use or deterioration. Depreciation in this project was estimated with a normal useful life. Below is the depreciation of each asset individually, the number of years of useful life was extracted from the SII website (see **Table 5**) [50].

4. Discussion

The technical evaluation of the biogas project from household organic waste for the production of electrical energy, self-consumption and sale of bio fertilizers, projects that the process is technically feasible mainly due to the fact of the substrate nowadays. It is a problem with high costs for the municipality, and for this project, it is free raw material.

For the start-up of the project, it is important to consider that the costs of the investment evaluated are mainly concentrated in the biodigester and the cogeneration, being 50% of the investment. This indicates that it is very important to know the real cost of this equipment. It is recommended to obtain quotes from several companies, in addition to calculating the dimensions, since this could affect the cost of the investment which would affect the profitability of the project.

For the execution of the project, the variability in time of electricity prices is a consideration. In this study, it was considered that energy production would be sold to the central interconnected system, but there is also another option that was not estimated since it is currently not very feasible. The sale of energy directly to companies, could generate contracts for long periods, but the investment of the installation of wiring and other costs, in the city of Panguipulli there does not currently exist a large company that could be a potential client.

It is important to recognize that a weakness of the project is its high investment cost, which means an entry barrier to the energy and fertilizer market. As was commented previously, the waste for another entity means an expense, but seeing it from this perspective that it is a potential income generator, in addition to being an environmentally friendly process, it provokes an acceptance by the surrounding communities and could be considered in the municipality plan.

The cash flow indicates that the project under the conditions defined in the technical and economic evaluation is profitable according to the economic indicator of net present value. It amounts to 214.099.637 CLP, an IRR of 15% and a recovery period of 6 years.

This is because the sale price of bio fertilizer is high, capable of absorbing almost all annual expenses, a high percentage of sales can be estimated, since the market for fertilizers in this area is great. The information previously presented allows us to answer the hypotheses; where the first two are accepted, the construction of a biogas plant in the Panguipulli commune is economically profitable and the volume of household organic waste in the Panguipulli commune makes it possible to construct a biogas plant, while the third hypothesis is refuted. The investment in the

NPV	**214.099.637**
IRR	15%
Payback	6 years

Table 6.
Results of economic indicators in CLP.

construction and implementation of a biogas plant in the commune of Panguipulli is recovered in 4 years.

The evidence of the results of the indicators economic showed that investment in the construction and implementation of a plant of biogas in the commune of Panguipulli is recovered in 6 years (see **Table 6**).

It is recommended that to reduce the risk of the project, the given climatic factor be considered, which is the greatest limitation for the development of biodigestion projects. This inconvenience can be reduced by implementing complementary heating to the biodigester and implementing proper insolation. In this way, by increasing biogas production, consequently, the generation power of kW will increase the profitability of the system. It is also suggested to include information on the location of the project, this will allow knowledge of environmental conditions, wind speed and direction.

The technical and economic evaluation of a biogas plant from household organic waste allowed a visualization of the economic profitability, points to consider and difficulties that will allow clarification of the situation to potential investors.

5. Conclusion

Currently, there is excessive growth in waste production at a worldwide level that leads to the search for new solutions that allow the reuse of waste in a sustainable way over time and friendly to the environment, within these options is biogas, that by means of a biodigester offers advantages for the waste treatment which generates a gaseous fuel, which can be used to generate electrical energy. It also generates a quality biofertilizer and with this, it is possible to reduce the environmental damage caused by accumulating this substrate in a sanitary landfill.

When analyzing the composition of the waste, it was calculated that 12 tons of household organic waste per day is generated in the Panguipulli commune. This allowed the size of an appropriate biodigester to store 40 days of retention, and thus generate 600 m^3 of biogas per day, which provides electrical power of the generator of 50 kW that allows a generation per year of 374,400 kW-year. Thanks to this, it can self-consume energy electricity and sell the rest to the central interconnected system.

This research has several characteristics that position it with a potential for biogas production, these are; availability of substrate use, geographic availability of the substrate, stable prices and costs and projected in time and finally to create a project that minimizes environmental impact.

Finally, the economic evaluation obtained a net present value (NPV) of the project evaluated to 15 years of 214,099,637 and an internal rate of return (IRR) of 15% to a real discount rate of 10%. The investment payback period is 6 years.

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Appendix 1: Cash flow in millions of Chilean pesos (CLP).

CASH FLOW	0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Income from the sale of biofertilizer	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1
Income from the sale of electricity	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5	86.5
Electric energy saving	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7
Total revenues	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2	202.2
Operation and maintenance costs		53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8	53.8
Land lease		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Total expenses	0	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4	57.4
Gross profit	0	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8	144.8
Tax	0	−39.1	−39.1	−39.1	−39.1	-39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1
Profit after tax	0	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7
Depreciation	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	1.4	1.4	1.4	1.4	1.4	34.2
Net Investments	540.0															
Investment VAT	102.6															
VAT recovery		102.6														
Working capital	163.5															
Recovery of working capital																163.3
Investment in intangibles	5.4															
capital flow	−811.5	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	139.9	107.0	107.0	107.0	107.0	107.0
Cumulative Cash Flow	−811.5	−671.6	−531.7	−391.8	−251.9	−112.0	27.9	167.8	307.7	447.6	587.4	694.5	801.5	908.6	1.015.6	1.122.6

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