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Hydroscrew Turbines Feasibility Study

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Affidavit

I, **MAURICIO RECALCATTI**, hereby declare

1. that I am the sole author of the present Master's Thesis, "HYDROSCREW TURBINES FEASIBILITY STUDY", 81 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

The growing demand for electric energy and the search for renewable and clean generation sources, refer to the study and manufacture of machines, equipment or devices capable of producing electricity with minimal losses from natural resources still available. From many diverse ways of generating this energy, in the Brazilian scenario, the hydroelectric plants gained great relevance due to the characteristics of the national territory. The large number of rivers and pluviometric precipitation in practically whole country results in a great potential of hydropower generation for Brazil. Thus, the small or micro Hydroelectric Generating Centers (MHP) are inserted in this context as an attractive alternative for the generation of clean energy with very low environmental impact. Due to their small size, these types of plants have low implementation costs, as well as causing less damage to the environment when compared to the Large Hydropower Plants (LPP) or other sources of energy, like coal and oil Power Plant. This study analyzes the economic viability for the implantation of Screw Turbines, by means of a real case study, in the Southern region of Brazil. For this purpose, asset valuation tools are used as net present value of the discounted cash flows and calculation of the internal rate of return of the Power Plant. The net present value (NPV) and the internal rate of return (IRR) of the Hydroelectric Generating Station are calculated based on the sales value of the energy obtained by the entrepreneurs in the last alternative energy auction. In view of the results obtained, concludes that the implementation of the Mini Hydropower Plant is feasible economically for all scenarios and adds more value to the shareholder than alternatives of the financial market of equivalent risk.

Keywords: Screw turbine, hydropower, energy production, renewable energy, Archimedean Turbines.

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Chapter 1

Introduction

1.1 Statement of the problem

Since the development of techniques linked to electric energy, one of the greatest human discoveries, the world is increasingly dependent on this type of energy. In the last decades, the planet has been suffering a rapid depletion of natural resources, with all the deleterious effects derived therefrom, such as global warming and the extinction of species. At the same time, life in modern society is increasingly dependent on energy, which leads to an obstinate search for increasing the generation, essential for the current way of life (Viana, 2015).

The production and use of energy are strongly related to the development of societies, bringing many benefits: the possibility of using electrical appliances, the preparation and preservation of food and thermal comfort in homes; the faster and more efficient transport of people and cargo; the great diversification of manufactured industries and products; among many others. However, they also have several negative impacts. In fact, the way energy is generated and used is the root of many of today's environmental problems (Goldemberg, 2003).

Within this context of consumption stimulus, there is an increase in energy demand and the need for growth with environmentally friendly technologies, and thus the opportunity arises to use alternative sources of energy that can meet this growing demand and act within the perspective of sustainable development.

Given this scenario, high importance must be given to five means of generating electricity which are the most important: hydro, thermal, nuclear, wind and solar. With regards to renewable and clean energy generation, the set is reduced to three types of generation (hydraulics, wind and solar). The hydroelectric plants, in the case of the Brazilian scenario, gain even more relevance because of the characteristics of the national territory. The large number of rivers and rainfall in practically whole country results in a great potential of hydropower generation for Brazil (Mancebo, 2013).

Since the end of the 19th century, hydroelectric plants have been playing an important role in generating energy in Brazil. The production of hydroelectric energy according to Müller (1995) consists in converting the potential energy of a river or reservoir to dynamic energy rotate the hydraulic turbines, which is connected to the generators, generating then the electric energy.

The energy generated in hydroelectric power plants does not depend on fossil fuels, but large power plants often generate significant environmental and social impacts resulting from the flooding of large areas and the need to remove people living in them. In some situations, the flooding of vast areas of forest is currently a significant emission of methane gas, one of the main causes of the greenhouse effect (Terra et al., 2008).

According to data from Ernst and Young (2008), Brazil will be the 5th largest consumer of electricity in the world by 2030. Until that date consumption will grow 4.4% per year on average. Data from the Energy Research Company (2014) show that Brazil needs to invest R$ 175 billion over the next ten years to supply the strong demand for electricity that will emerge.

Given that Brazil is one of the largest countries in the world in terms of river water wealth, with emphasis on surface waters concentrated mainly in rivers of various sizes, the application of small hydroelectric plants is certainly one of the alternatives for decreasing dependence on large hydropower plants. These units still represent most of the country's electricity supply and have already shown to be susceptible to supply crises, especially in times of prolonged drought (Vesentini, 2009).

Thus, Mini Hydropower is inserted in this context as a source of clean energy and of very low environmental impact, since the flooded area is minimal (or in some cases null).

Following this context, Archimedean screw turbines are a promising form of hydropower generation. They offer an alternative generator design that provide greater efficiencies for low-fall and low-flow locations with significant reductions in impacts to the environment both in terms of atmospheric gas emissions and of effects on the natural environment (Kozyn, Lubitz, 2015).

According to Stergiopoulou and Kalkani (2013), Screw turbines convert hydraulic energy into mechanical energy, using the available hydraulic energy, natural or artificial water courses, under conditions of continuous flow and constant rotation, with the aid of rotary screw rotor with angular velocity ω and torque M, inclined or with horizontal axis; and kinetic hydroelectric energy under free-flowing conditions, such as rivers (small or large), open channels, to current tides.

The adaptation of the Archimedes screw for use in turbines, for primary drive in Hydropower plants, presents a simple construction with few moving components: basically, a helicoid connected to an axis and supported by two bearings. The helicoid rotates freely within a steel tube, the gap remains small to the wall of the tube. The correct inclination of the screw-tube assembly causes the water, accelerated by gravity, to force the helicoid to rotate, activating the shaft, which is coupled to a pulley, speed multiplier or generator (Niederle, 2016).

Despite all the advantages presented, the construction of Mini Hydropower plants is still an investment that presents many uncertainties and risks for the investors. Such risks are inherent to the construction process - the technical (hydraulic and energy) constraints are like those of the major works in the sector, and they are also more sensitive to the value of the project. In this way, a rigorous process of construction planning and control becomes vital to the success of the implementation of the project (Makaron, 2012; Queiroz, 2010).

The economic feasibility analysis of investment in Mini Hydroelectric Power Plants is very important to stimulate the application of private resources in the sector, to increase the use of the existing potential, as well as create the necessary conditions for economic growth.

In this context, there is an interest in deepening the study on this generation source and the critical success points for the viability of the Mini Hydropower projects, as an alternative to the expansion of the energy matrix with renewable sources.

1.2 Objectives

The objective of this work is to analyze the economic and financial viability of the implantation of a Mini Hydropower plant, with the use of a screw-type turbine, taking as a model a Power Plant in implementation phase in Santa Catarina, southern region of Brazil.

The costs for the assembly of the plant were collected from the company owner and equipment suppliers, as well as the amounts of revenues and expenses incurred for one year. This work presented here can be used as a reference for verifying the feasibility of implementing new projects in Brazil.

As secondary objectives, we sought:

- Review the literature on Mini Hydropower plants which includes describing their characteristics, the political-regulatory context, and the concepts necessary for projecting the cash flow of Mini Hydropower plants projects;
- List the metrics for the economic-financial feasibility analysis usually used in infrastructure projects, and the meaning of each one;
- Identify the main risks and obstacles related to Mini Hydropower plant projects.

1.3 Significance of the study

Since the development of techniques linked to electric energy, one of the greatest human discoveries, the world is increasingly dependent on this type of energy. Several great evolutions of mankind have been derived from these techniques: storage of food in a refrigerator, mass media such as radio and television, computers, among many others, until the present day, where technology is very dependent on electric energy (Mancebo, 2013).

According to data from Ernst Young (2008), Brazil will be the fifth largest consumer of electricity in the world in 2030. Until that date consumption will grow on average 4.4% per year. Data from the Energy Research Company (EPE) (2010) show that Brazil needs to invest R$ 175 billion over the next 10 years to meet the strong demand for electricity that will arise, considering an average GDP growth of 5% per year.

Brazil, like other emerging economies, still faces a series of economic, political and social challenges of a structural nature. Therefore, the investment in electric energy in

Brazil is fundamental, both for economic development and for social development. In turn, the difficulty and bureaucracy to approve projects of great magnitude, which runs up against environmental and social issues, causes Brazil to lag behind its demand. As a result, entrepreneurs are looking for alternatives to small-scale projects such as Mini Hydropower plants, which cause less environmental impacts and can be built without major obstacles (Candido, 2012).

In the late 1990s and early 2000s, the mismatch between growth and investments in large hydroelectric plants required the Ministry of Mines and Energy (MME) to act more to ensure conditions for private enterprise to implement new generating units, in order to optimize the supply and distribution of energy. In this way, the Mini and Small Hydropower plants resurfaced in the national scenario (Souza et al., 2005).

In 2013, the total installed capacity of electric power generation in Brazil (including public service and auto producers) reached approximately 127 GW. However, although the Brazilian hydroelectric potential is estimated at 260 GW, only 25% of this total is effectively used for power generation. The remainder refers to the existence of generating parks that have not yet been exploited, either due to environmental obstacles, projects that are still technically or economically unviable, or simply due to the difficulties of access to the region (Aneel, 2016).

Brazil is in a privileged situation with respect to its electric energy matrix, with 82% of the sources being renewable. However, the Small and Mini Hydropower plants account for only 2% of the energy generated in the country (Aneel, 2010).

Thus, Mini Hydropower plants can play an important role in complementing the generation of the energy matrix, including the fact that they are disseminated throughout the country, which reduces costs with the installation of large transmission lines. They are also a guarantee of regional supply, which alleviates the national system (Borges, 2011).

In this context, Archimedean screw turbines are a promising form of hydropower generation. They offer an alternative generator design for typical large-scale hydropower stations that provide greater efficiencies for low-fall and low-flow locations with significant reductions in impacts to the environment both in terms of atmospheric gas emissions, and of effects on the natural environment (Kozyn, Lubitz, 2015).

1.4 Contribution

Unlike other construction projects, the investor who chooses to enter the electrical sector is subjected to a very complex process, both from the technical point of view (civil project and construction), as well as the influence of natural aspects in the project, complexity and regulatory bureaucracy. Often projects are not completed, just as they often reach the end with a budget and deadline much higher than the initial forecast (Makaron, 2012).

Before starting the design of a Mini Hydropower plant, an economic feasibility study is necessary, and for this, one must estimate the cost and benefit of Mini Hydropower. It is important that this analysis allows the comparison between the different possibilities of arrangement and dimensioning of the components.

Investment analysis is one of the key tools in long-term investment decisions and involves the application of large amounts with medium- and long-term returns. It also assists in obtaining the perception of time, financial volume and risks involved in a more realistic project.

Companies have to structure themselves internally in order to control possible risks and monitor non-investor risks. Thus, the economic feasibility analysis model demonstrated in this work is of fundamental importance for the analysis of future investments and will serve as an apprenticeship for investors who plan to enter the market or are in the construction process.

1.5 Outline of study

The study presented is divided into 5 chapters. Chapter 1 serves as the introduction of the work. It presents the theme of the work, the central objective, the secondary objectives, the central question and the methodology. Also explained in this introduction were the justifications and relevance of the subject addressed.

Chapter 2 contemplates an overview of the Brazilian energy sector, addressing the historical and current contexts, and how the Mini Hydropower plants are inserted in it.

Also, in this chapter are described the technical concepts of Screw Turbines and the regulatory processes of this type of power plant.

Chapter 3 presents a bibliographical review of the concepts of economic-financial feasibility analysis of Mini Hydropower plant projects. Also analyzed are the elements that make up the cash flow of the construction project of a power plant.

Chapter 4 presents the case study that is the central theme of this work. It will present the technical data of the Mini Hydropower plant in question, as well as the development of the physical aspects about the future generation of electric energy. With the data established, the necessary calculations will be made to obtain the estimated power and energy value, which will be supplied by the hydroelectric plant to the electric system. Next, the calculation of the expected cash flow of the proposed Mini Hydropower plant investment will be developed in order to arrive at the values necessary for the decision making on the feasibility of applying capital according to the expected return.

Finally, in Chapter 5 a discussion is made regarding the data found, and the conclusions of the present study are presented.

Chapter 2

Theoretical background and literature review

This chapter aims to present introductory concepts on sustainable development and hydroelectricity, and to align the basic knowledge on the subject, in order to allow a better understanding of the proposed analysis.

The first part addresses the question of renewable energy and its importance today. Next, the history of the Brazilian electric sector is passed on from the moment it was constituted until the present day. Also, a contextualization of the small hydropower generation is made.

The second part deals with the general concepts about Mini Hydropower plants and Archimedes Screw turbines, from concept, technical applications, relevant legislation and their classification.

2.1 Renewable energy and environment

On face of globalization, sustainability has become an everyday theme present in our lives.

The term sustainable development covers a set of paradigms for the use of natural resources to meet human needs. This term was first mentioned in 1987 in the Brundtland Report of the United Nations which stated that sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." It should consider environmental, economic and socio-political sustainability (Torresi, 2010).

According to Nascimento (2012), the first dimension of sustainable development usually mentioned is environmental. It assumes that the model of production and consumption is compatible with the material base on which the economy is based, as a subsystem of the natural environment. It is, therefore, to produce and consume in a way that ensures that ecosystems can maintain their self-repair.

This same author reports that the second dimension, the economic dimension, implies an increase in the efficiency of production and consumption and decrease for need of natural resources, with emphasis on resources like fossil fuels, water and minerals. This is what some call eco-efficiency, which implies in a continuous technological innovation that will lead us out of the fossil energy cycle (coal, oil and gas) and expand the dematerialization of the economy.

The third and last dimension is social. A sustainable society assumes that all citizens have the minimum necessary for a decent life and that no one absorbs goods, natural resources and energy that are harmful to others. This means eradicating poverty and defining the acceptable pattern of inequality, delimiting minimum and maximum limits of access to material goods (Nascimento, 2012).

The growing demand for electric energy and the search for renewable and clean generation sources, refer to the study and manufacture of machines, equipment or devices capable of producing electricity with minimal losses from natural resources still available.

From many ways of generating the energy, for the Brazilian scenario, the hydroelectric plants gain great relevance due to the characteristics of the national territory. The large number of rivers and rainfall in practically whole country results in a great potential of hydropower generation. The hydroelectric power generation sources have the advantage of a clean transformation of the natural resource, without generating direct pollution. The generation projects purposes contemplate the protection of forests, with rescue of fauna and repopulation of fish (Apesc, 2017).

Energy sources are present in nature as renewable and non-renewable energy. According to Riquelme (2008), renewable energies are all those whose utilization rate is lower than their renewal rate, that is, energies that originate from permanent and inexhaustible sources. This group includes hydroelectric power, biofuels (obtained from biomass), solar (photovoltaic) energy and wind energy. They are known as clean energies because they do not generate significant pollutants during the production process or alternatively because they represent an option to the main or traditional energy sources of a given country (usually fossil fuels), allowing a diversification of its energy matrix.

Non-renewable energies, however, are natural resources that, when used, can no longer be restored in a useful term by human action or by nature. They come from fossil fuels, such as: oil, natural gas, natural coal, uranium among other exhaustible elements (Riquelme,2008; Viana, 2015).

According to Goldemberg and Lucon (2007), current patterns of energy production and consumption are based on fossil sources, which generate emissions of local pollutants, greenhouse gases and jeopardize long-term supply on the planet. We must change these patterns by stimulating renewable energies.

Currently, 61% of the energy produced in world's largest economies are derived from fossil fuel sources, followed by nuclear energy with 21%, energy from 14%, and energy geothermal, wind and solar represent only 4% of world production (Candido; Santos, 2012).

The energy landscape in Brazil is not different from the rest of the world, there is a predominance for oil use. However, the Brazilian energy matrix has a strong hydraulic base in its composition, as well as a significant share of energy from biomass, divided between traditional biomass (firewood) and modern biomass (wood, cane, ethanol and other sources, ethanol due to the program of use of this fuel in the transport sector) (Goldemberg and Lucon, 2007).

As mentioned by Vianna (2009), the development of renewable sources is a favorable way to protect the environment and, in a way, offers the opportunity to complement the decentralized supply of energy, generating economic and social benefits.

2.2 Hydroelectric power - concepts and history in Brazil

Hydroelectric plants use the movement of water from a river to generate electricity. The water is used to rotate the hydraulic turbines that are coupled to an electric generator, thus, converting kinetic energy of the movement of water into mechanical energy to rotate the generator (Miranda, 2012).

To produce hydroelectric energy, it is necessary to integrate several variables: river flow, height of water fall, variations in water availability according to the period, installed capacity, type of turbine used, dam type reservoir and location (Mancebo, 2013).

Since the end of the 19th century, hydroelectric power stations have been playing an important role in power generation in Brazil. The first hydroelectric plant in Brazil was a Mini Hydroelectric Power Plant, in 1883, in the municipality of Diamantina, Minas Gerais, with the purpose of supplying energy to a diamond mine (Makaron, 2012).

It was only with the beginning of industrialization that the use of electric energy was boosted. This fact is mainly due to the increase of population concentration in urban centers and, since 1920, hydroelectricity was predominant in Brazilian energy generation, representing about 80% of the installed power (or about 780 MW) and going in the opposite direction to the world trend, where thermoelectricity predominated based on mineral coal (Menezes, 2015).

According to Mancebo (2013), the first plant in Brazil intended for public purposes (illumination of nearby cities) was also built in the state of Minas Gerais, more precisely in Juiz de Fora. Known as the Marmelos-Zero power plant as showen in Figure 2.1, it became operational in 1889 and had a capacity of 4 MW. It was the first large hydroelectric plant for the time.

Figure 2.1: Power Plant Marmelos-Zero, in Juiz de Fora (Science Center, Juiz de Fora Federal University)

According to Makaron (2012), the increasing urbanization and the industrialization that occurred between the years 1890 and 1900, led to the installation of several other small power plants, mainly to meet the demand of public lighting, mining, processing of agricultural products and the supply of textile and sawmill industries existing in that state, as well as in other locations in the country.

The beginning hydroelectric plants construction in Brazil is closely linked to small producers and distributors, farms and industries that sought self-sufficiency in energy. In addition, from the point of view of public supply, the only way to bring electricity to small cities in Brazil was through the construction of small power plants in a nearby location. Thus, until the middle of the 20th century, several small hydroelectric plants were installed in the countryside (Mancebo, 2013).

According to Menezes (2015), the Brazilian electricity transmission system formed an industrial organization made by an archipelago of electric islands with regulations still incipient. It was organized in an independent and isolated manner and served preferentially to the largest urban centers, located around the cities of Rio de Janeiro and São Paulo.

The regulation of the Brazilian electricity sector began with the Water Code, which began in 1906. Among other things, the concession period of thirty years was established, and it could be extended for another 20 years; the need for federal authorization or concession for the construction of transmission lines or distribution networks; and assuring the right of the public power to fiscalize technical, financial and accounting companies of the sector (Ganim, 2009).

The process of installing Mini Hydropower plants expanded rapidly from 1920 to 1930, when the number of companies increased from 306 to 1,009, with all of them generally operating small hydroelectric plants (WWF-BRASIL, 2004). This growth continued until the 1940s, even at lower rates. Therefore, at this time Mini Hydropower plants made up the vast majority of enterprises.

During the 1950s, Brazilian companies started to participate in the construction of large hydroelectric projects. The large urban centers, increasingly industrialized, needed a more efficient energy supply over the years (Mancebo, 2013).

In 1957 came the regulation no. 41,019, which regulated the electric energy services in Brazil. Since then, the division of services in the electric sector has been clear: the public companies were delegated the expansion of installed capacity in Brazil, both in generation and transmission, while private concessionaires, foreign or not, were delegated the distribution services. The Ministry of Mines and Energy was created by Law no. 3.782, of 1960, aiming at the public administration of the sector, and Eletrobrás, by Law no. 3.890-A, from 1961, to administer and finance public investments in the sector, previously assigned to the National Bank for Economic Development (Palomino, 2009).

The creation of Eletrobrás in 1962 and the compulsory loan in 1964 consolidated the dominance of the State in the expansion of supply in the electric sector. Eletrobrás centralized the planning, financing and expansion of supply (Tolmasquim, 2011).

From second half of the 20th century until the 1990s, due to the economy benefits, large power plants have been installed in Brazil. For this reason, throughout this period, Mini Hydropower plants have been practically neglected. But with the change in the Brazilian energy framework, they have emerged as a way out for the country's lack of energy. In this way, the government did not hesitate to promote the expansion of small hydropower plants, which occurs in a decentralized manner and with a shorter time for commissioning (Clemente, 2001).

Later, the country received large investments in the energy sector. Two clear examples are the construction of the Tucuruí (between 1974 and 1984) and Itaipu (between 1975 and 1982) plants with installed capacities of 8,340 MW and 14,000 MW, respectively, which are still the largest Brazilian plants in operation. In addition to these investments in power generation, there was a large capital injection in the power transmission sector. This was necessary because of the geographical conditions, characterized by a vast territory and different climatic conditions favorable or not to the generation of hydroelectric energy (Mancebo, 2013).

The framework that characterized the interconnection of the Brazilian electrical system was the creation of the National Electric System Operator in 1998, which would be responsible for operating the National Interconnected Electricity System. This system, built throughout the middle decades of the 20th century onwards, aims to better energy distribution and increase system reliability (Palomino, 2009).

In this context, Mini Hydropower plants have fulfilled - and do - an important role throughout this evolution of the Brazilian energy sector, since they can supply the demand for energy in isolated areas and other remote communities, where energy distribution by company's concessions is not enough, or nonexistent. Due to their characteristics, power plants with a capacity of less than 3MW constitute a type of enterprise that allows better attendance to the needs of small urban centers and rural regions, as small producers, farms and small industries, since, in most of cases, complement the provision already made by the system (Mancebo, 2013).

Therefore, through Aneel, benefits were granted, procedures were simplified in order to increase economic-financial attractiveness and to allow more investors access to this type of enterprise.

2.2.1 Overview of the energy sector in Brazil

Brazil has a hydrographic network very favorable to the hydroelectric generation, which has rivers of great extension, width and depth, fed by tropical rains that maintain one of the largest reserves of fresh water in the world. In addition, the historical and political context experienced by the country since the beginning of the generation of energy, have also contributed to a very convenient scenario for the installation of hydroelectric dams of all sizes and in different localities of the national territory (Mancebo, 2013).

All these characteristics allow Brazil to have a strong presence of hydroelectricity in its energy matrix, which according to Aneel (2017a) corresponds to 61.18%, and Mini Hydropower plants correspond to only 0.37%, as shown in Figure 2.2, in conjunction with Table 2.1.

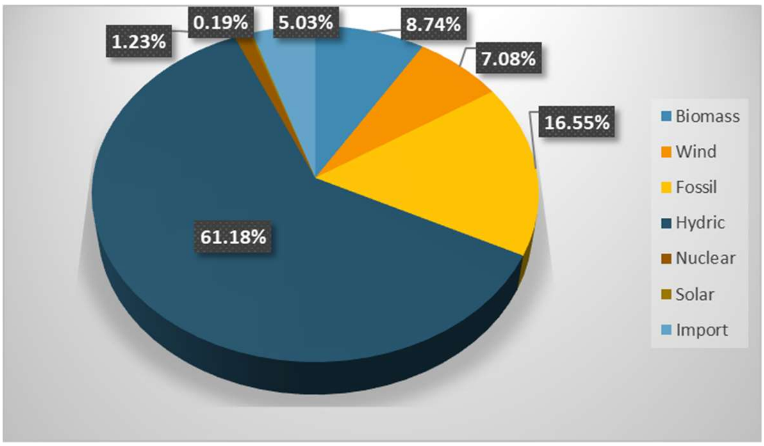

Figure 2.2: Energy matrix of Brazil.

Employment in operation in Brazil				
Type	**Quantity**	**Granting Power (kW)**	**Supervised Power (kW)**	**%**
MHP	618	562.368	564.824	0,37
WIN	470	11.551.739	11.498.043	7,45
SHP	431	4.970.991	4.955.175	3,21
PP	60	386.248	311.732	0,2
LHP	219	101.188.678	93.877.884	60,84
TP	2.933	42.494.226	41.099.661	26,64
TNP	2	1.990.000	1.990.000	1,29
Total	**4.733**	**163.144.250**	**154.297.319**	100

Table 2.1: Employment in operation in Brazil (Aneel's Generation Information Bank, 2017)

According to Aneel (2017b), the Granting Power, observed only in Figure 2.1, is equal to the power considered in the Granting Act. The Supervised Power is the one considered from the commercial operation of the first generating unit. Thus, the final percentages of the Figure and graph are related to the Controlled Power.

According to table 2.1, total hydroelectricity (totaling MHP, SHP and LHP) accounts for almost 100 GW of power surveyed in the country and is the main source of electricity corresponding to approximately 65% of the total energy generated, according to Aneel data. The graph also shows that the energy matrix in Brazil had 618 Mini Hydropower Plants (MHP) in operation, with a total power of 564 Megawatts (MW).

The dimensions of the transmission network are determined by the size of the plant, which should transmit the energy to the center of consumption. The larger the plant, the greater the capacity to serve large centers and consequently requires the construction of large transmission lines. In the case of Mini and Small Hydropower plants, installed near small waterfalls, which usually supply points close to the generation plant, they do not need such sophisticated facilities to transmit energy (Mancebo, 2013).

According to Epe (2007), about 98% of the Brazilian electricity system, in terms of generation and load, is interconnected, which allows the optimized use of energy resources, by exploiting the hydrological and market diversities existing between the basins and sub -water basins, electrical subsystems and systems and geographic regions. The rest of the load consists of a large number of isolated systems, usually of small size.

According to Aneel's Generation Information Bank (BIG), up to October 2017, there were 6 Mini Hydropower plants under construction (Table 2.2), with power granted of 9,398 kW and 37 other projects of this type granted (with construction not started), which add up to more than 26,531 MW, according to Aneel data (Table 2.3).

Employment in Construction			
Type	**Quantity**	**Granting Power (kW)**	**%**
MHP	6	9.398	0,08
WIN	148	3.414.550	30,44
SHP	27	369.980	3,3
PP	32	911.400	8,13
LHP	6	1.922.100	17,14
TP	32	3.238.154	28,87
TNP	1	1.350.000	12,04
Total	**252**	**11.215.582**	100

Table 2.2: Development under construction in Brazil (Aneel's Generation Information Bank, 2017)

Employment with uninitiated construction			
Type	**Quantity**	**Granting Power (kW)**	**%**
MHP	37	26.531	0,22
CGU	1	50	0
WIN	130	2.829.210	23,19
SHP	134	1.758.220	14,41
PP	65	1.651.093	13,53
LHP	8	731.540	6
TP	179	5.203.993	42,65
Total	**554**	**12.200.637**	100

Table 2.3: Employment with uninitiated construction in Brazil (Aneel's Generation Information Bank, 2017)

In 2013, the total installed capacity of electric power generation in Brazil (including public service and auto-producers) reached approximately 127 GW. However, although the Brazilian hydroelectric potential is estimated at 260 GW, only 25% of this total is effectively used for power generation. The remainder refers to the existence of generating parks that have not yet been exploited, either due to environmental obstacles, projects that are still technically or economically unviable, or simply due to the difficulties of access to the region (Aneel, 2016).

Therefore, the country needs to improve its investments in the energy matrix because, despite having a vast hydrographic basin, it does not use all its generation potential, and it is necessary to import energy produced in other South American countries.

2.3 Mini Hydropower

The increase in world demand for electricity, together with the growing movement towards ecologically sustainable activities, has encouraged countries to seek alternative sources of energy supply. The development of these sources is aimed at increasing the supply of energy and, at the same time, reducing the world's dependence on fossil fuels and nuclear (Silva, 2016).

According to Mancebo (2013), there is currently a growing demand for hydroelectric plants with potentials lower than 3,000 kW, which are, according to Aneel, classified as Mini Hydropower Plants. Several factors can be identified as generators of this demand, among them the current governmental incentive, the low financial investment needed to start this type of business, the low environmental impact, among others. The graph below (Figure 2.3) shows that there was an increase in the number of Mini Hydropower plants installed in Brazil.

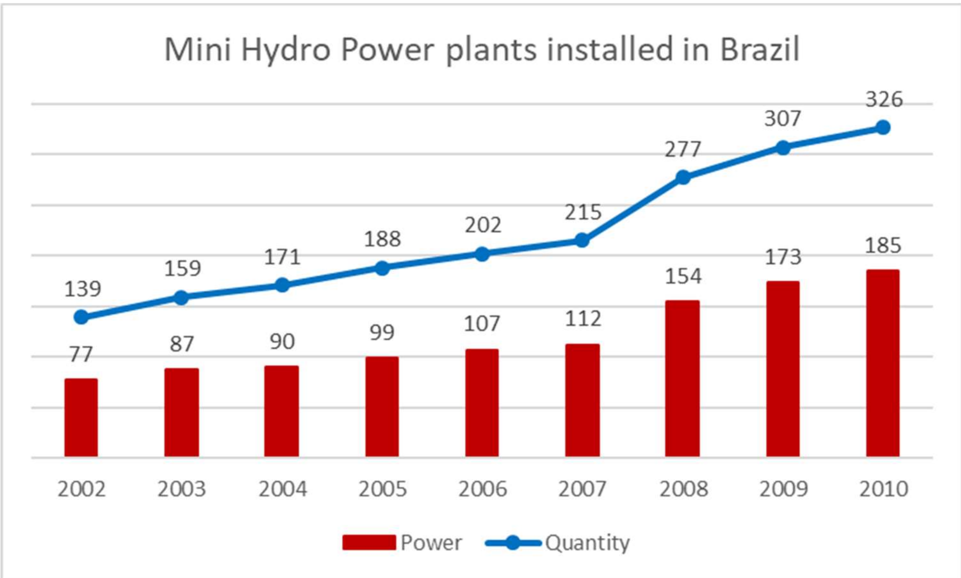

Figure 2.3: Mini Hydropower plants installed in Brazil

Until October 2017, the national energy matrix had 618 Mini Hydropower Plants in operation. These small power plants, with a total power of 564 Megawatts (MW), represent 0.37% of the Brazilian energy matrix (Aneel, 2017).

The Mini Hydropower plants are hydraulic structures built in rivers, which provide for the generation of energy. The process involved in the production of electricity in a Mini Hydropower plant depends on a number of variables, such as river flow, the amount of water available over a given period of time, ground unevenness, technology used and demand for energy (Aneel, 2008).

Unlikely large hydroelectric plants, whose development is associated with the construction of large dams, Mini Hydropower plant, because they are smaller, have the main advantage of greater simplicity in design and operation. These enterprises generally do not use reservoirs to store large volumes of water and usually operate by water, allowing the continuous passage of the river with a stable nominal capacity (Reis, 2003; Ardizzon et al., 2014).

The fundamental principle of the operation of a Mini Hydropower plant is related to the use of a dam store water. The stored water activates a hydraulic turbine and this, in turn, effects the transformation of hydraulic energy into mechanics. The electricity generated is transmitted and distributed through transmission lines to consumers and the water used is returned to the river (Reis, 2003; Makaron, 2012).

According to Reis (2003), Mini Hydropower plants have three main characteristics. The first is associated with the issue of having rapid input into the power system and flexibility to rapidly change the amount of power provided to the system because of changes in demand. The second concerns the fact that they have low operating, maintenance and energy production costs. The third, and last, refers to its smoother (soft) environmental insertion properties.

The construction of Mini Hydropower plants represents an important alternative for the production of renewable energy, since it does not produce as much environmental impact caused by the great intervention in the nature of the large reservoirs, having, for the most part, small and medium sized water falls, not even interfering in the regime of the watercourse. These authors also point out that Mini Hydropower plants can be used to complement large systems due to the lower investment risk. In addition to the important environmental factor, Mini Hydropower plants have other advantages, such as affordable cost, shorter implementation time and investment maturation, and their surplus energy can be made available to concessionaires to acquire this energy (Silva e Maniesi, 2005).

The Mini Hydropower plants have technical, environmental and financial advantages, when compared to the large projects within this sector. In fact, there is a greater probability of finding generation potentials at Mini Hydropower plants closer to the consumer centers, saving the cost of transmission; and it is also observed that Mini Hydropower plants cause lower environmental impacts, especially those resulting from flooded areas. In addition, it is also verified that: a) it is feasible to make the necessary investments only with contributions made by the private sector; b) it is possible to realize simplifications in the design when compared to larger generations; c) it is possible to consider a significant reduction of the time for the realization and execution of the project; and d) gains derived from the remote centralized operation for a set of Mini Hydropower plants can be counted (Martinez, 1994; Makaron, 2012).

Another great advantage presented is that the Mini Hydropower plants provide reservoirs used for irrigation, human consumption during periods of drought and tourism. In times of floods, they also collaborate to mitigate the impact of floods (Apesc, 2017).

According to Makaron (2012), the specific construction process of Mini Hydropower plants presents important regulatory simplifications in relation to large hydroelectric plants. Among them can be mentioned: the authorization process by Aneel; the process of obtaining the environmental licenses granted by the competent bodies; and tax benefits, such as the discount on the transportation system use tariff.

The Mini Hydropower plants can play an important role in complementing the generation of the energy matrix, including the fact that they are disseminated throughout the country, which reduces costs with the installation of large transmission lines. They are also a guarantee of regional supply, which alleviates the national system (Borges, 2011).

With discounted transmission rates, tax incentives, and less complexity in environmental licensing processes, investing in Mini Hydropower plants has become a great opportunity for many large energy groups in Brazil, such as Energias do Brasil and CPFL Energia. But it was not only them, mutual funds also detected in the segment a very great potential for their applications, with good margin of profitability for their assets (Moraes, 2010).

Since Mini Hydropower plants are a real alternative – more sustainable – for the expansion of installed capacity in Brazil, the implementation and modernization of these projects is a natural and indispensable process.

2.3.1 Mini Hydropower Regulatory Environment

To start up, the Hydroelectric Generating Plants must be registered with the National Electric Energy Agency (ANEEL). According to Decree no. 2003/1996, the use of hydraulic potentials of up to 3 MW does not depend on concession or authorization but must be communicated to the regulatory and supervisory body of the granting authority for registration purposes (Aneel, 2013).

This registration process for Mini Hydropower plants is free of charge. Entrepreneurs interested may choose between two registries: one with energy allocation for exclusive use and another for the commercialization of electric energy.

The regulatory environment in which the Mini Hydropower plants-type enterprise is inserted involves legal and regulatory instruments that deal with existing incentives, the conditions for contracting the energy produced and the minimum requirements for the connection of distributed generation in the networks owned by the distributors. We can highlight the following:

- Art. 26, paragraph 1 of Law No. 9,427 of December 26, 1996, as amended by Law 11,488, of June 15, 2007, established the jurisdiction of ANEEL to define the percentage of discount in the tariffs for the use of distribution systems and TUST and TUSD – not less than 50% for projects classified as small hydroelectric power stations – Small Hydropower plants (installed capacity greater than 3 MW and less than or equal to 30 MW) and those of a hydroelectric source with power equal to or less than 3 MW, as well as for generating plants based on solar, wind, biomass and qualified cogeneration, whose power injected into the transmission or distribution systems is less than or equal to 30 MW, focusing on the production and consumption of the energy marketed by the facilities.

- According to § 5 of art. 26 of Law no. 10.438, of April 26, 2002, the undertakings mentioned in the previous paragraph may commercialize electric energy with a consumer or a group of consumers assembled by a pool of interests of fact or right, whose load is greater or 500 kW, subject to ANEEL regulations.
- Art. 3 of Law No. 10,438 of 2002, amended by Law No. 10,762 of November 11, 2003, established the Proinfa Alternative Energy Sources Incentive Program, with the objective of increasing the share of electricity produced by ventures based on wind power, small hydroelectric power stations and biomass.
- Law 10.848, of March 15, 2004, determined that the distributors belonging to the National Interconnected System (SIN) should guarantee the service to the totality of its market. For that, energy must be acquired, among other hypotheses, through auctions promoted by ANEEL, from new and existing plants, as well as from alternative sources.
- In addition, art. 2º, §8º, allows the distributor to acquire part of the energy of enterprises characterized as distributed generation, observing the limits of hiring and transfer to the tariffs of consumers, as well as of the plants inserted in Proinfa.
- Art. 34 of the Decree regulated the Annual Reference Value (VR), which is a transfer limit for the final consumers' tariffs on the energy purchased by the distributor in public calls. ANEEL publishes the annual values of the VR, calculated on the basis of the results of the energy auctions performed, weighing the prices obtained and the amounts contracted in each auction.

2.3.2 Rates

The Tariff for the Use of the Transmission System – TUST, applicable to all users of the transmission system, is intended to compensate the installations belonging to the

Basic Network, that is, only those provided in item I, art. 3 of Normative Resolution No. 067/2004.

According to Homologatory Resolution Nº 1,244, of December 13, 2011, the unit value of PROINFA is R $ 5.82 / MWh, which, plus taxes of Social Integration Program – PIS and Contribution for Social Security Financing – COFINS, results in the Use of the Transmission System – TUST, in the amount of R$ 6.42 / MWh, for non-cumulative opt-in transmitters and R$ 6.04 / MWh for opting broadcasters by the cumulative tax regime.

The information published in the annexes to ANEEL Resolution No. 1.244 contains the tariffs for the use of transmission facilities that are components of the basic network of the national interconnected system and of other transmission facilities on a shared basis applicable to the distribution concessionaires. According to this resolution, the average value of TUST applied by Eletrosul, the concessionaire operating in the region where Mini Hydropower plant is located, is subject to a study of this work of R $ 4.20 per kW*month for peak and 2.09 per considering the discounts provided for in Normative Resolution No. 77, mentioned in item 2.3.1, which provides for a minimum discount of 50% in the tariffs for the use of transmission systems – TUST and TUSD for hydroelectric projects of equal power or less than 3 MW.

For the calculation of the sales value of energy generated by Mini Hydropower plants under study, the Reference Value of R$ 141.72 per MWh from the year 2012, published by ANEEL, will be used.

According to Technical Note No. 0043/2010-SRD / ANEEL, Small and Mini Hydropower plants are exempt from paying financial compensation to municipalities affected by the plant's reservoir. In addition, they are exempt from annual payment of 1% of their net operating revenue in research and development of the electricity sector

2.4 Archimedes Screw Turbine

Archimedes Screw turbines are a form of renewable and unconventional hydroelectric power generation that has emerged in the last decades and have been adopted in places with low falls in Europe due to high efficiency, competitive costs and low environmental impacts (Lyons, Lubitz, 2013).

The Archimedean Screw working as a pump has been known since antiquity. The discovery of the Archimedes Screw was credited to the Greek physicist Archimedes and this screw was originally used to pump water from low to high elevation, for irrigation in the Nile Delta and to pump ships (Rosly, 2006).

In 1819, the French engineer Claude Louis Marie Henri Navier (1785-1836) suggested the use of the Archimedes screw as a type of water wheel. In 1922, William Moerscher patented the hydrodynamic screw turbine in America (Renewable First, 2015).

An Archimedes screw consists of an inner (central) cylindrical axis, around which one or more helical surfaces are wrapped orthogonal to the surface of the cylinder. The resulting geometry is much like a conventional screw. The screw is typically engaged in a tilted cylindrical chute and is free to rotate along the axial length. When used as a pump, the lower end of the Archimedes screw is placed in water and mechanically turned. This rotation causes the buckets of water to become trapped between the surfaces of the helical plane. As the screw rotates, the water buckets are thrown from the axial length of the screw to a higher elevation (Brada, 1999; Lubitz et al., 2014).

A view of a three-blade screw, and farmers using a conventional hand screw pump to irrigate their land in the Egyptian Nile delta, are shown in Figure 2.4.

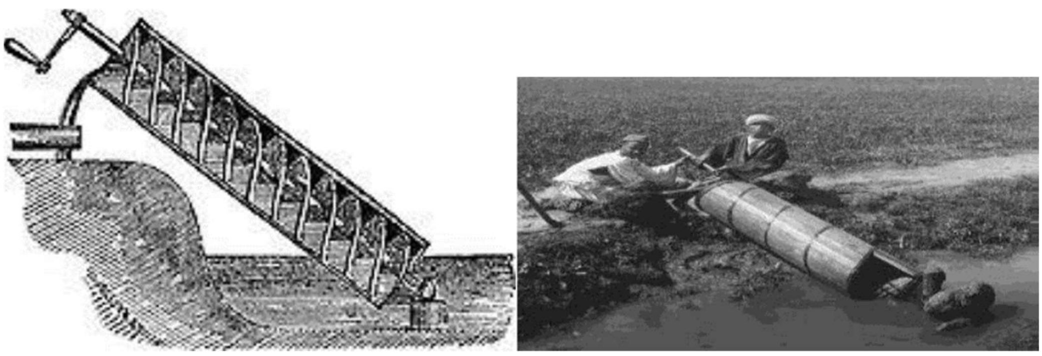

Figure 2.4: Archimedes Screw pumps (Stergiopoulou 2013)

Archimedes Screw turbines are defined based on the reversal of the principle of pumping operation of the Archimedes screw, and use the available hydraulic power for energy production for low drop differences (Rohmer et al., 2004; Hellmann, 2003).

The first operational turbine of this type was deployed in Europe in 1994 (Western Renewable Energy, Mann Power, 2015). According to Nuernbergk & Rorres (2013), the highly advanced gearbox that the device requires was not available until recently, which is why it took time to use it.

At least 400 Archimedes screw turbines have been installed in Europe since 1993 (Lashofer et al., 2012) and more are under construction; however, there are currently few Power Plants in other parts of the world (Lubitz et al., 2014).

2.4.1. Screw Turbines Basic Principles

Archimedes Screw turbines are an adaptation of the old technology of the Archimedes screw pump, and work in reverse. The water is introduced at the top of the screw and flows through it, from a high altitude to a low altitude. As the water passes through the screw, the formed water buckets create a pressure difference on the opposite sides of the helical plane surfaces. Due to the shape of the flat surfaces, a component of this differential pressure force always acts in a direction normal to the central cylindrical axis, causing the screw to rotate. By placing a gearbox and generator on the screw shaft, the mechanical rotation can be converted into electrical energy (Kozyn, Lubitz; 2015).

The turbine extracts the kinetic energy from the river or stream by its conversion into mechanical energy. The generator receives the mechanical energy and converts it into electrical energy that is then supplied to the grid (Rohmer et al., 2014).

According to this same author, the power captured by the turbine is transmitted to the generator. If the generator is a standard machine, a speed multiplier is inserted into the shaft to adjust to the grid frequency as the Screw Turbine runs at a rather low speed. It is possible to remove the multiplier to have a direct coupling but requires the electric generator to run at the same rational speed as the turbine, for this particular case the grid frequency has to be adjusted by other means. A view of an Archimedes Screw Turbine is shown in Figure 2.5.

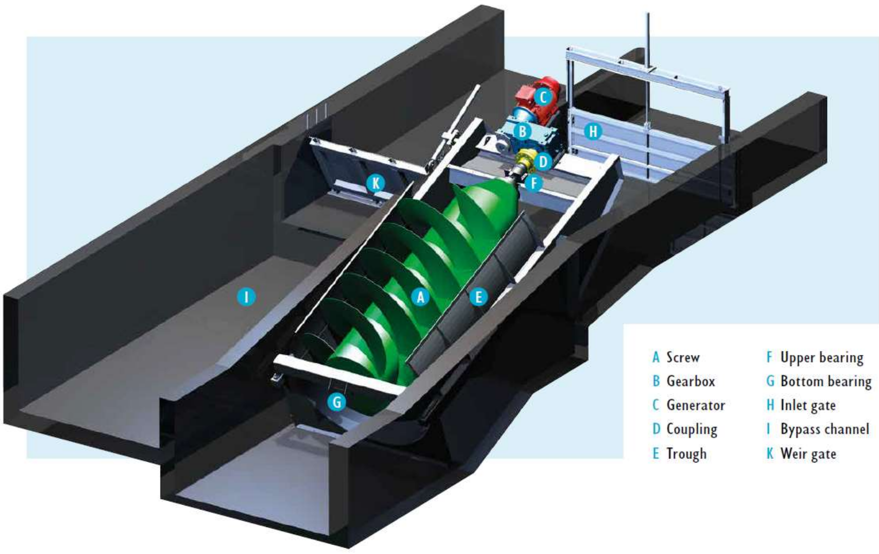

Figure 2.5: Archimedes Screw turbine (Spaans Babcock, 2016)

In modern times, this screw can be used in a variety of applications, such as wastewater treatment plants and also as a hydroelectric turbine in the production of electricity (Rosly, 2006).

According to Kantert (2008), the Archimedean screw turbine is generally applied in rivers with relatively low falls (from 1 m to 10 m) and low flows (up to about 10 m3 / s).

Data from available studies show that Archimedes Screw Turbines are very efficient. In a study developed by Prof. Hiroshi Takimoto, from the University of Toyama (Japan), a small Screw Turbine presented an efficiency of 60% (Japan for Sustainability 2008). Brada (1999) reported efficiencies of around 80% in an operational Screw Turbine in Germany. Recent research in commercial installations of Screw Turbines in Europe, developed by Hawle et al. (2012), an average operating efficiency of 69% was found, and maximum efficiencies greater than 75% were found for this type of system.

Archimedes turbine can be used in situations where there is a concern for the preservation and care of the environment and wildlife (Kantert, 2008). One of the advantages of screw turbines is that they are considered to be the friendliest for fish, from the turbines available on the market. Part of the reason for this is due to the low speeds of rotation in which the device operates. Moreover, due to its method of operation, there are no large variations in shear stress or pressure which could be harmful (Fishtek Consulting, 2008).

Another great advantage of the Archimedes Turbines screw is simplified civil engineering works and foundations. Since the bolts do not have draft tubes or discharge sinks, this means that the depth of any concrete work on the downstream side of the screw is relatively shallow, which reduces construction costs. The civil works are also relatively simple, the main part being the load base underneath the upper and lower bearings (Renewable First, 2015).

Environmental, hydrological and geological problems, besides economic ones, restrict the construction of large plants. Thus, the use of small water falls is a viable option in the composition of the national energy matrix (Pineli, 2005).

2.4.2. Design Criteria

According to the study by Muller and Senior (2009) on the performance criteria of the Archimedes screw turbine, the maximum efficiency that the device can achieve is limited by a combination of turbine geometry and mechanical losses in the system. In addition, the ideal design of any turbine is always a tradeoff between the best theory and the cost required to create it (Waters, 2015).

Although the peak efficiency of the Archimedean Screw turbine does not exceed that of a Bulb turbine, it offers continuity both forward and reverse if placed horizontally due to the symmetrical nature of the design. This method of operation mainly uses the water velocity to transform the device. Moreover, the efficiency of the device does not change excessively when the flow rate deviates from the optimal value (Nuernbergk & Rorres, 2013).

According to Jash Engineering Limited (2012) study, there are many advantages to using Screw turbines in a Micro Hydropower Plant. These include:

- Archimedean Screw turbines are eco-friendly in nature and have zero pollutant effect on the environment;
- it is not necessary to cut trees and carry out the movement of people;
- cavitation and erosion cannot affect the turbine;

- have quick and easy installation;
- efficiency will remain the same in relation to variable loads;
- small canals, ponds and rivers etc. can be used as resources;
- negligible maintenance and low operating costs;
- the wildlife habitat will not be affected.

2.5 Summary and Conclusions:

This chapter began with the approach of renewable energy and the environment demonstrating the growing demand for electricity and the search for renewable and clean generation sources. We have seen the three dimensions of sustainable development and the importance of prioritizing the use of renewable energies. It was seen that the Brazilian energy matrix has a strong hydraulic base in its composition, due to the characteristics of the national territory. The large number of rivers and pluviometric precipitation in practically the whole country results in a great potential of hydropower generation for Brazil.

Next, the contextualization of consumption and generation of energy in Brazil was made. It has been seen that Brazil has a hydrographic network that is very favorable to the hydroelectric generation, which has plateau rivers of great extension, width and depth, fed by tropical rains that maintain one of the largest reserves of fresh water in the world. In addition, Brazil has a strong tendency to increase per capita consumption, as one of the factors that result from economic development and an increase in the level of industrial and commercial activity.

Afterwards, the concepts and definition of Mini Hydropower plants, the relevant legislation and the technical advantages presented by this type of machine were reviewed. Then there was a review on the Screw Turbines, describing the concepts, the history the main advantages. It has been observed that the turbine Archimedes Screw turbine can be used in situations where there is a concern with the preservation and care of the environment and wildlife.

Chapter 3

Technical concepts applied to the economic and financial viability of Mini hydropower projects

The objective of this chapter is to make a bibliographical review of the technical concepts necessary for the elaboration of an economic and financial evaluation model of a Mini Hydropower construction project, based on the existing bibliography.

3.1 Economic Viability Analysis

Designing a Mini Hydropower project requires a substantial initial investment and often returns slower than ordinary financial applications. Therefore, it is necessary to evaluate the design of a Mini Hydropower through an economic feasibility study, in order to reduce the risks of the use in question and verify if the project offers good prospects of economic use in terms of hydraulic potential (Mancebo, 2013).

According to Pineli (2005) and Alves (2010), in the electric power sector, the metric most used to measure investments in new generation projects is the invested capital divided by the generation capacity, in MW or KW. Thus, the value of the plant is determined according to its productive capacity.

For Schreiber (1977), a good method is to evaluate the cost of generating energy, or, in other words, the cost of kWh generated at the plant. The elements of the assessment of viability are therefore:

- initial investments;
- annual expenses;
- generation in kWh / year.

3.2 Initial Investments

All the expenses necessary for the construction of the hydroelectric plant until its entry into operation are considered as initial investments. According to Queiroz (2010), the largest portion of the cost of a Mini Hydropower is the initial investment.

Helfert (1997) argues that investment is the source of growth that underpins explicit competitive management strategies; in other words, the initial investment made is the source of revenue in the future, so it is seen as a recoverable expense. Investments can be subdivided into:

3.2.1 Cost of construction

According to Pineli (2005), the cost of construction includes, in addition to the costs for the construction of the various components of the plant, such as dam, spillway, powerhouse, electromechanical equipment, transmission line, etc., such as access roads and all works in the area of the future reservoir such as: cleaning and deforestation.

3.2.2 Cost of preparatory work

The works to be considered are: reconnaissance of the region, hydrographic and hydrometric works, geological surveys, topographic works, geotechnical surveys, elaboration of the project from the feasibility report to the executive project (Helfert, 1997).

3.2.3 Expropriations and indemnities

To this item belong: purchase and expropriation of lands, indemnities regarding impaired rights and devaluation of properties.

3.2.4 General costs

According to Moraes (2010), they are represented by all administrative expenses during the construction of the plant. They are not fixed assets, machines or equipment, but they involve the administration, security, and disbursements to establish the company before the responsible government agencies.

3.2.5 Unforeseen

Any damages caused by elementary events such as extraordinary floods, very rainy periods, very long floods, lack of material, etc. are unforeseeable in their real value. They are calculated as a percentage of the total investment and can vary approximately between five and twelve percent.

3.2.6 Interest on capital invested in construction

It is called opportunity cost and refers to the gains that would be obtained from unused alternatives. Represents interest on capital invested in construction that does not yet earn income (Helfert, 1997).

3.2.7 Investments in Fixed Assets

Corresponds to the portion of investments made in fixed assets required by the company. They can be machines, real estate, buildings, among others, everything that has a long useful life and stay fixed in the company (Moraes, 2010). Depending on the purpose of the venture, this tends to be the most relevant initial investment.

3.2.8 Unrecoverable Costs

Unrecoverable costs are not considered initial investments, but it is important to understand their definition.

This cost is one that occurred before the project was accepted or rejected. (Ross et al., 2008). Expenses with market research, land prospecting and feasibility studies may be considered unrecoverable, as the company can do dozens of studies in various markets and locations before proceeding with the project.

3.3 Annual expenses

3.3.1 Annual indirect expenses

According to Helfert (1997), all the monetary expenses are related to the invested capital. For example, dividends paid to shareholders in the case of a corporation, which must be at least equal to the rate of interest on capital invested.

3.3.2 Annual direct expenses

The plant's operating expenses comprise the following items:

3.3.2.1 General Administration Expenses

They comprise all the administrative expenses not directly related to the operation of the plant, such as: direction, secretariat, cash, accounting, office maintenance, car service and maintenance, as well as taxes and fees (Helfert, 1997).

3.3.2.2 Operating personnel salaries

The salaries of operating personnel should be assessed individually for each plant. The number of personnel depends on the number of daily operating hours of the plant, the legal number of daily or weekly working hours and the size of the plant and its complementary facilities and constructions (Pineli, 2005).

3.3.2.3 Maintenance and repair costs

It contains the expenses of maintenance and repairs of several components of a hydroelectric plant in percentage on the new value. It is good to remember that the maintenance of roads, railways, improvements, etc. displaced because of the construction of the plant belongs to the person in charge before relocation (Pineli, 2005).

3.3.2.4 Expenses with operating materials

According to Helfert (1997), the consumption of operating materials, such as lubricating oil, grease, tow, diesel oil, cleaning material, etc., is almost independent of the load factor. Expenditure can be estimated at 0.5 to 1% of the investments in machinery.

3.4 Energy production and the cost price of kWh

According to Pineli (2005) and Schreiber (1977), it is necessary to deduct from the total production of energy the own consumption of the plant in the machines and auxiliary facilities for turbines and generators and the consumption of lighting, air conditioning and ventilation, the operations of gates and valves, etc. This results in the production available at the generator terminals. Dividing the sum of the annual expenses (calculated as indicated) by the production yields the cost of kWh. When the cost of the kWh available for the supply of the transmission network is necessary, it should be included in the annual expenses, those to be made with the transformers and the distribution station, as well as the energy losses in them.

3.5 Initial Working Capital

For Dolabela (2006), the Initial Working Capital, or the initial cash balance, is the monetary value that the company has in cash on the first day of operation, money that is necessary to pay the debt until a balance between the current inputs and the current outputs from the cash flow are available.

According to Mancebo (2013), the contingency reserve, defined as 12% of the total initial planned investments, serves to reduce the risk of the work if it needs a larger capital contribution than planned and to be the initial working capital amount of the enterprise.

According to this same author, working capital is of fundamental importance for companies, especially at the beginning of their operations, to pay their current expenses. If the company does not pay attention to this initial resource, it can spend all the investment in the construction of the plant and will not have sufficient resources to pay its initial expenses, such as maintenance and operation, due to the time gap between payment and revenue.

Thus, the contingency reserve considered in the initial investment calculation will be considered the cash reserve required to maintain the operation, which means the working capital of the enterprise.

3.6 Investment Financing

In the current scenario in Brazil, the National Development Bank (BNDES) is the main source of credit for long-term financing for infrastructure works, including hydroelectric plants. The available financing lines are 1) BNDES Finem, for projects with large investment; 2) BNDES Automatic, for projects with investment up to R $ 10 million, already approved the limit increase to R$ 20 million and 3) BNDES Finame, exclusive for financing new machinery and equipment. This financing is carried out through BNDES financial agents (commercial banks, development banks, credit cooperatives, etc.) (Makaron, 2012).

According to the same author, the Mini Hydro credit lines have the maximum amortization time of 14 years and the entrepreneur has to contribute at least 20% of the value of the investment. The cost of financing is composed of the Long-Term Interest Rate, plus a BNDES remuneration spred, generally defined as 1% per annum and a rate that remunerates the BNDES credit risk, assessed individually for each borrower.

3.7 Transmission line

The transmission line, one of the critical points in the feasibility analysis and construction of a plant, has to be planned and monitored from the beginning of the project. It can generate serious problems with delays in the project schedule and cost, and even make the overall investment unviable (Makaron, 2012).

According to the same author, access to the transmission and distribution system is guaranteed to all agents in the industry. Aneel Resolution 281/99 defines the general conditions for contracting access and Module 3 Prodiste, elaborated by the National System Operator (NOS), defines the conditions of access to transmission lines. It is the responsibility of the interested party to construct the line that will connect the plant to the basic network, an asset that will later be donated to the local distributor. Who defines the place of connection to the local system is the concessionaire, as well as the tariff that will be charged for the use of the distribution system (TUSD) or transmission system (TUST).

The interested party must make a formal request to connect to the system, transmit to the concessionaire the basic information of the project, which will have a deadline of up to 30 days to communicate to the applicant the place of connection, the technical requirements of the line and equipment and the respective order. It is at this moment that the investor will be able to sculpt more accurately the costs involved with transmission lines.

Once formalized the conditions of connection, the contract for the use of the distribution / transmission system is signed and thereafter, the entrepreneur can start a construction. As defined by Resolution No. 281, of October 1, 1999, of the entrepreneur's responsibility: I - the entire metering system for electrical energy, necessary for the connection; II - reimburse the distributor for the cost of acquisition and implementation of the rear meter and the data communication system, in the case of access to the other transmission facilities, not members of the Basic Network, in distribution rooms; and III - civil works and adjustments of the installations associated with the metering system, in the case of access to other transmission facilities, not part of the Basic Network, or to the facilities owned by the distributor.

The calculation of the fees is done individually for each plant at the time of the access query. The calculation is based on nodal prices. As described in Resolution No. 281 of October 1, 1999, the Methodology for the calculation of tariffs and nodal charges is based on the estimated costs that users impose on the network in the periods of maximum demand, calculated from the costs of investment, operation and maintenance of the minimum network capable of carrying the flows that occur in such periods.

3.7.1 Rate of Use of the Transmission System

The average value applied by Eletrosul, the concessionaire operating in the region where Mini Hydropower plant is located, is R$ 4.20 per kW.m. for the peak and 2.09 per kW.m. for low demand, considering the discounts provided for in Normative Resolution No. 77, which provides a reduction of at least 50% in the tariffs for the use of transmission systems for hydroelectric projects with a power of 3 MW or less.

3.7.2 Electricity Services Inspection Fee

A TFSEE - Taxa de Fiscalização de Serviços de Energia Elétrica foi criada, pela Lei nº. 9.427, de 26/12/1996, e regulamentada pelo Decreto nº. 2.410, de 28/11/1997, com a finalidade de constituir a receita da Agência Nacional de Energia Elétrica - ANEEL para cobertura das suas despesas administrativas e operacionais. A Lei nº. 12.783, de 11/01/2013, reduziu a TFSEE de 0,5% (cinco décimos por cento) para 0,4% (quatro décimos por cento) do valor econômico agregado pelo concessionário, permissionário ou autorizado, inclusive no caso de produção independente e autoprodução, na exploração de serviços e instalações de energia elétrica.

The Inspection Fee for Electric Energy Services – TFSEE (1) was created by Law no. 9,427, dated December 26, 1996, and regulated by Decree no. 2,410, dated 11/28/1997.

The law no. 12,783, dated 01/01/2013, changed the fee from 0.5% (five tenths percent) to 0.4% (four tenths percent) of the economic value aggregated by the concessionaire, the permittee or authorized, including in the case of production independent and self-production, in the operation of electric energy services and installations.

$$TF = 0.4\% \times (BETU \times P) \quad (1)$$

with

TF = annual value of the inspection fee for Self-Producers and Independent Producers of Electric Energy, expressed in R$;

BETU = typical average value of the annual benefit derived from the exploration of the energy generation activity, applicable to Autoproducers and Independent Producers of Electric Energy, expressed in R$ / kW;

P = nominal power installed in commercial operation up to December 31 of the previous year, pro rate, expressed in kW.

3.8 Insurance

It is very important to contract the insurance to cover operational risks / loss of profit that will ensure the entrepreneur against any damages caused by the stoppage of the operation of the plant. Another insurance that must be contracted is the civil liability insurance, which will ensure the entrepreneur against third parties (Gouvêa, 2012).

3.9 Depreciation of Assets

Depreciation is an accounting way of considering the wear and tear of machines and equipment as part of production costs. It is an important concept to be discussed as it is a cost that does not affect cash flows. The faster an asset is depreciated, the lower the accounting earnings at the beginning of the asset's life, representing lower expenses with income tax. Therefore, the "cash" profit increases, since the tax burden decreases (Alves, 2010).

According to this same author, the legislation allows for several ways of accounting for depreciation, which comes as a cost, reducing the accounting profits, on which income taxes are levied. The more the asset is depreciated, the less taxes will be paid.

The faster the depreciation, the lower the tax will occur earlier, and the sooner the cash is obtained, the greater the present value of the total amount.

Most of the resources destined to the construction and operation of a Small Hydropower Plant are represented by investments in fixed assets. Thus, the value of the depreciation of the assets becomes fundamental in the calculation of the cost of the energy produced (Pineli, 2005).

The depreciation of property, plant and equipment, according to the Federal Revenue, corresponds to the decrease in the value of the elements classified there, resulting from wear and tear, nature action or normal obsolescence. This loss in the value of the assets will be periodically recorded in the cost or expense accounts (depreciation charges for the calculation period), which will be recorded as accumulated depreciation registration accounts, classified as permanent asset rectification accounts (RIR / 1999, art. 305).

The rate of depreciation will be fixed according to the period during which the economic use of the good can be expected in the production of its income (RIR / 1999, article 310). The rate applicable to each case is obtained by dividing 100% (one hundred percent) of the value of the asset by the useful life in months, quarters or years, thus calculating the monthly, quarterly or annual rates to be used.

3.10 Statement of Income for the Year

The Statement of Income is a statement of the increases and decreases in shareholders' equity, as revenues normally represent an increase in assets, thus increasing stockholders' equity (Matarazzo, 2002).

According to Ross et al. (2008), usually the first items disclosed in the report are the revenues and expenses of the company's operating activities. Financial expenses and revenues, among other accounts, are shown below. After the taxes on the result, we have the Net Profit.

3.11 Estimate of Gross Revenue

The installed capacity is different from the assured power, since the machines do not work with the maximum capacity, because the river flow does not remain constant during the year (Mancebo, 2013).

Another important factor to consider are the transmission losses that occurred during the transport of the energy through the transmission line. According to articles published by CERPCH, the factor used is around 5 to 10%. For the present study, the rate of 5% for the loss factor in the transmission line will be used since the distance traveled by the energy produced until its sale to the customer concessionaire is very small.

3.12 Taxes and charges

The law no. 9,718 establishes that legal entities that have total gross revenue equal to or less than R$ 48,000,000.00 in the previous calendar year, or R$ 4,000,000.00 multiplied by the number of months in activity in the calendar year may enter into the presumed profit regime.

Regarding the gross revenue of a Mini Hydropower plant business, the main taxes levied are: the inspection fee for electric power services, ICMS, PIS, COFINS and transmission charges. On income after operating expenses and costs of products sold, income tax and social contribution on net income (Alves, 2010).

3.13 Debt Amortization

According to Alves (2010), the debt to be contracted by the company should be paid in periodic installments, there being two main possibilities for the calculation of installments and amortization, defined at the time of contracting the loan. The main amortization models are the uniform payment system (Price) and the constant amortization system (SAC).

According to this same author, by the Price system, the amount to be paid in each installment does not change over the periods, which is the uniform equivalent value of the total to be paid. The interest paid in period is equal to the cost of financing multiplied by the balance due in the previous period. The amortized amount in the period is equal to the difference between the amount paid in the installment and the interest paid in the period. The debit balance is the previous debit balance less the amortization of the period.

In the system of constant amortization (SAC), the amortized value is equal, in all payments, to the total amount to be paid divided by the number of periods in which the payments will be made. The interest paid in period is equal to the outstanding balance in the previous period multiplied by the cost of financing. As in the SAC system, the debt balance in the period is equal to the previous debt balance less the amount amortized in the period (Alves, 2010).

3.14 Cost-benefit analysis

The costs of a project involve acquisition of land, possible relocations of cities or towns, construction of physical structures, purchase of equipment, interest during construction, operation and maintenance, among others. On the other hand, the benefits of a hydroelectric plant are equivalent to the energy gains that the work will bring to the system in which it will be integrated, measured by the economic valorization of the increases of assured energy. These gains depend on the arrangement and efficiency of the equipment, the hydrological availability, among other factors. (Fortunato et al., 1990). The relation of cost and benefit results in a simple parameter to calculate and much used in the comparison and selection of projects, even between projects of different sources and proportions.

The analysis begins with the definition of basic energy parameters: assured energy, available power and secondary energy. These parameters allow to evaluate and compare the alternatives according to the available potential. The contribution of assured energy is considered as a decision variable, it represents the amount of energy that can be generated, directly linked to the revenue of the enterprise (Martinez, 1994).

Thus, according to this same author, the energy parameters can be transformed into economic values, allowing the comparison of the total costs of the alternatives. Assuming the assured energy and the estimated total cost of the potential, the unit cost of the capacity, in R$ / MWh, also known as cost / benefit of the plant, is determined. This is one of the key indexes used to compare generation projects.

The cost / benefit index or cost of installed power is calculated according to the following equation:

$$\mathrm{CBI} = \mathrm{CC}/\mathrm{IP} \quad (2)$$

with

CBI = Cost benefit index

CC = Construction Cost

IP =Installed Power

3.15 Considerations

Estimating costs, in general, is a complex process. However, it is vital to the success of the project, and the more detailed and realistic it is, the easier the process of control, the identification of deviations, corrections and continuous adaptations, so as to avoid that the initial cost estimate not overcome (Venkataraman and Pinto, 2008).

According to these same authors, a well-designed cost estimate is the main means to evaluate the feasibility of the project. In addition to being a source of information for the definition and quantification of funding, it provides a standard against which expenses actually incurred during the course of the project can be compared, and serves as a basis for cost control.

An underestimated cost estimate can cause serious problems in the course of construction, especially with regard to cash flow management and the cost of raising additional capital. The main causes of low initial estimates are: underestimation of the complexity and magnitude of the project; the evaluation of the project done in isolation, without considering the impact of the other external activities; and unexpected technical difficulties as a result of a poor initial project or unforeseen technical complexity. External factors such as inflation, interest rate, environmental issues and exchange rate fluctuations may also interfere with the projected initial cost, especially in the case of a longer project construction schedule (Venkataraman and Pinto, 2008).

3.16 Economic-financial analysis

3.16.1 Investment analysis

According to Luizio (2011), the basic concept underlying the evaluation of an investment project is that the value of this project lies in its ability to generate cash over time long enough to pay the opportunity cost of financial capital. Thus, the feasibility analysis of a project is, in particular, studies carried out to verify if the project has possibilities of economic-financial success.

Damodaran (2002) says that the key to a successful investment is not only knowing the value of a given asset, but also what the sources of that asset are. Complex models of financial valuation depend on innumerable variables and assumptions that involve many uncertainties, and the end result is often debatable. However, as Ehrlich (2005) has already said, there is no escaping models to portray reality, even if in a simplified way. The model serves not only to understand reality, but also to aid decision making.

The economic analysis for the implementation of a Mini Hydropower is made using several methods and tools. After estimating all the costs involved for each alternative considered, the diagram of the cash flow of the enterprise is elaborated, with the respective revenues (inflows) and expenses (outflows), to analyze the economic viability in the projected horizon.

One of the most important phases in the elaboration of a long-term investment project is the application of quantitative methods of economic evaluation. It is necessary to verify with the greatest possible accuracy, the income possibilities of capital applications (Pineli, 2005).

The quantitative methods of economic analysis of investments can be classified into two groups: those that do not take into account the value of money over time, and those that consider this variation through the criterion of discounted cash flow. Due to the greater conceptual rigor and importance for long-term decisions, priority attention is given to the methods that make up the second group (Martins & Assaf Neto, 1988).

According to Oliveira (2012), the most used methods are; first net present value method - NPV (discounted cash flow); second the internal rate of return on investment

(IRR) method; third minimum required revenue method (or minimum attractiveness rate - TMA). In addition to these, other methods such as simple payback time (simple payback), discounted payback time (payback discounted), benefit / cost ratio among others are also widely used.

The analysis of the model proposed in this work will be defined by four indices: Net Present Value (NPV); Simple payback time (simple payback); Returned investment payback time (Discounted payback); and Internal Rate of Return.

3.16.2 Values over time

The preliminary concepts necessary for the analysis to be presented are the present value (PV) and future value (VF) of the money. Such concepts derive from the idea that a currency unit has a different value today compared to a given amount of time due to the opportunity cost or discount rate associated with that amount of money. Therefore, in order to define the future value VF of a given PV present value, three variables are required: the value itself, the time that VF differs from VP, and the discount rate associated with that value, which may be an interest rate or a cost of opportunity (Ehrlich, 2005).

3.16.3 Net Present Value - NPV

One of the techniques widely used and recognized in project evaluation is the Net Present Value – NPV (3). According to Gitman (2001), it is a sophisticated technique of capital budget analysis, obtained by subtracting the initial investment of a project, from the present value of its cash inflow flows, discounting a rate that is equal to the cost of capital of the company or a minimum rate of attractiveness.

According to Macedo (2002), the NPV can be seen as a gain provided by the asset, because it represents how much the future cash flows are above the initial investment. Luizio (2011) points out that the NPV depends on the remuneration sought by the capital providers, taking into account the cost of resources invested over time and the risks involved.

For the calculation of NPV we have:

$$VPL = \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} - CF_0 \quad (3)$$

with

CF = represents the cash flow (benefit) of the period;

i0 = the investment processed at time zero;

Ij = the value of the investment forecast in each subsequent period;

The method of calculating net present value requires the definition by the company of a minimum acceptable discount rate, which will be used in the various cash flows. Thus, the NPV will indicate the result between the amount invested and the economic benefits updated (Pineli, 2005).

The higher the net present value at a given discount rate, the more desirable the project is to the company, the greater its earning potential. According to Oliveira (2012), this implies that when the NPV is positive, the project under analysis has a rate of return higher than the interest rate considered, and therefore covers the cost of capital of the company and should be accepted. On the other hand, if the net present value is less than zero (negative NPV), it means that the initial investment is greater than the project return, which should be rejected, while not attractive to other investment opportunities available in the project. Marketplace.

According to Damodaran (2001), there are two techniques for calculating the net present value: first to evaluate the result considering the share ownership of the project; second to evaluate the result considering the company as a whole, which includes, in addition to the equity interest, the participation of the other rights holders in the company. Although the two approaches use different definitions, they will produce consistent estimates of value, provided that the same set of assumptions is used in both.

3.16.4 Simple return on investment time - Simple Payback

This method is used to determine the period of time necessary for capital (investment value) to be recovered through the benefits produced (net cash flow), depending on the resources invested (Pineli, 2005; Oliveira, 2012).

This method has advantages: simplicity of calculation, intuitive meaning and realization of the liquidity measure of the project. However, it has the disadvantage of ignoring the cash flows that are generated after the payback period (Stalla, 2000). In addition, Braga (1998) points out as another deficiency of this method, the fact that it does not recognize the value of money over time, that is, it does not consider the cost of money or interest on it in a given period.

As a criterion for using Simple Payback (4) as a decision-making tool, Gitman (1997) defines that if the payback period is less than the maximum acceptable payback period, the project is accepted; if the payback period is greater than the maximum acceptable payback period, the project is rejected. That is, to decide whether to invest or not, the payback period should be confronted, with the time limit set by the company as default.

Therefore, it is the generating company that will preliminarily define, within its business strategies, the maximum term tolerated for the return of the investment, for comparisons between alternatives considering this method.

$$\mathrm{TRIs} = \mathrm{I}/\mathrm{BA} \tag{4}$$

with

TRIs - simple return on investment time;

I - Total investment;

BA - Annual net benefit.

According to Pineli (2005), the payback period has still been used as an indicator of the risk factor of an enterprise. The risk involved increases as the term of return increases. The occurrence of greater uncertainties in the economic environment, with monetary liquidity constraints, indicates that the shorter the deadlines to be defined as the standard limit by investors.

Furthermore, according to this same author, the criteria of fixation of the standard period of payback are understood as strongly subjective. They take into account the stability of the currency, long-term yield prospects, stability of the flow of income, inflationary effects, product stability, profitability required by the company plus others.

Simple Payback alone does not represent conclusive results, and the use of this criterion for decision on an investment should be taken as an auxiliary measure, using other more sophisticated criteria in completing the information.

3.16.5 Discounted return on investment time - Discounted payback

The Discounted return on investment time - TRId (Discounted Payback), defines the number of years it takes to recover the cost of an investment from the present value of the cash flow generated by the project using the cost of capital of the project as a discount rate (Stalla, 2000).

The discounted Payback method is similar to the simple Payback method, with the advantage that it considers the value of money in time (the annual net benefit is brought to present value by applying an update according to the considered interest rate), that is, discounted cash flow from the project (Oliveira, 2012).

Thus, an investment is acceptable if its discounted payback period is less than a pre-specified number of years (Ross et al., 2008).

3.16.6 Internal Rate of Return on Investment - IRR

The Internal Rate of Return is the rate of return required to match the current value of net cash inflows to the current value of the disbursements related to the net investment (Braga, 1998; Silva, 2009). In other words, it represents the profitability generated by a project.

Another possible definition for the Internal Rate of Return (5) is the discount rate that makes the NPV of an investment opportunity equal to zero. (Makaron, 2012)

$$IRR = \sum_{j=0}^{n} \frac{CF_j}{(1+i)^j} = 0 \quad (5)$$

with

IRR = Internal rate of return

FCj = Net cash flow at time i

N = Project duration

i = periodic equivalent rate of return (IRR)

In order to evaluate investment proposals, the calculation of the IRR requires, basically, the knowledge of the amounts of capital expenditure (or expenditures, if the investment provides more than one cash disbursement), and of the incremental cash flows generated exclusively by the decision (Martins & Assaf Neto, 1988).

It is important to note that the IRR represents only one of the criteria for analyzing the investment. It reflects a result which is based on expected cash flow forecasts. Accepting or not a project is a choice based on comparing alternatives. The IRR will always be compared with the minimum rate of return required by the company (investor) (Pineli, 2005).

As a decision criterion, Stalla (2000) clarifies that if the IRR of a project is greater than the cost of capital to finance it, the project will add value to the shareholder and thus must be accepted. However, if the IRR of the project is lower than the capital cost of the financing, the project must be abandoned because the company's applications will be yielding less than the cost of the resources used.

According to Pineli (2005), the Internal Rate of Return (IRR) will always be compared with the minimum rate of return required by the company (investor). This rate is defined as the Minimum Attractiveness Rate (TMA) and takes into account some variables, such as: (1) Inflation: the investor wants his resources to be corrected for the inflation of the period. Thus, your assets will remain at constant real values. Therefore, the expected return should be sufficient to compensate for inflation; (2) Opportunity cost: the resources to be invested will be withdrawn from other applications which have a profitability. Thus, the gains that could be obtained from unused alternatives represent the opportunity cost of the project. (3) Risk: every investment carries some risk. It is necessary to estimate it so that the return is compatible. (4) Profit: It is necessary that the return of invested capital provides a sufficient profit to its owner, depending on his entrepreneurial activity.

According to Gitman (1997), IRR is possibly the most used technique for the evaluation of investment alternatives. However, it is worth mentioning that, from a purely theoretical point of view, NPV is the best technique for capital budget analysis. The technique assumes that all the cash inflows generated by the investment are reinvested in the cost of capital of the company. The use of the IRR implies a reinvestment at an often-high rate, given by the IRR. Since the cost of capital tends to be a reasonable estimate of the rate at which the firm could reinvest, its cash inflows, the use of VL, as its more conservative and realistic reinvestment rate, is theoretically preferable.

3.16.7 Cost of Capital

Capital cost, also known as opportunity cost of capital, can be defined as the minimum required return on that capital, given the risk involved. (Alves, 2010). Represents the opportunity cost that investors expect to get from applying the resources in a project.

According to Pineli (2005), the discount rate to be used in the economic-financial analysis of an enterprise is based on the interest rate expressed by the cost of capital that will be used. The capital to be invested is obtained at the market value, that is, at the opportunity cost. This can be represented by the interest rate under which the resource needed for the investment is obtained or withdrawn from another application.

According to this same author, the rate of return of the undertaking under analysis should be higher than the one where the capital is applied, otherwise the investor will suffer. Thus, for the investment to be accepted it is necessary that its Internal Rate of Return is greater or equal to the cost of capital.

The model most commonly used to calculate the cost of capital is the CAPM - Capital Assets Pricing Model (6). According to Gitman (2004), CAPM is a model that links non-diversifiable risk to return for all assets. Its equation is:

$$ke = \mathrm{RF} + \beta * (\mathrm{km} - \mathrm{RF}) + \varepsilon \qquad (6)$$

with

Ke = the expected minimum return on the asset (in our case, the opportunity cost of capital)

RF = the risk free rate;

β = a relative measure of non-diversifiable risk (Gitman, 2007). Indicates the degree of variability of the return of an asset in response to a change in market return;

Km = the expected return on the market, so the component (Km - RF) makes up the market risk premium. Damodaran (2002) establishes three main methods to measure such a variable: risk premium implied by the market, research with market agents or historical risk premium. On choosing which method is most appropriate, Damodaran argues that there is no approach that works for all types of analysis. He says that by considering market neutrality (that assets are not being traded substantially below or above their intrinsic prices), the most accurate risk premium for the future is the risk implied by the market.

ε = the "noise" of the model, a specific risk of the asset or market in which it is inserted.

According to Doehler (2002), in the CAPM model, the expected capital gain invested in a company, which will represent its cost of capital, is a function of the market return, expressed by the risk that the securities traded on the stock exchange have. These papers constitute a financial asset, which contains a risk linked to the expectation of the virtual investor in the business they represent.

3.16.8 Weighted Capital Cost

The weighted average cost of capital – WACC (7) is used to convert future cash flow into present value for all investors (Makaron, 2012).

The WACC considers the cost of capital and the cost of the company's debt, according to the debt / equity structure of the asset. Its equation is:

$$\mathrm{WACC} = \mathrm{D} * \mathrm{kd} + \mathrm{E} * \frac{\mathrm{ke}}{\mathrm{D}} + \mathrm{E} \qquad (7)$$

with

D = the net debt of the company (gross debt minus net cash);

E = the company's equity;

Ke = the cost of capital;

Kd = the weighted cost of debt after tax. The weighted cost of debt is calculated by weighting each annual interest rate paid by the size of the corresponding financing line.

According to Makaron (2012) there are three steps to determining the cost of capital weighted: the first step is to determine the capital structure for the project evaluated, which will provide the market value weights in the formula; the second step is to estimate the cost of financing other than ordinary capital, which is relatively easy, since the financing is predominantly made by the National Bank for Economic and Social Development (BNDES); the third step is the estimated cost of financing by ordinary capital. For this, the authors approach two methodologies: either by the use of the capital goods pricing model (CAPM), or by the use of the arbitrage pricing model (APM).

3.16.9 Discounted Cash Flow (DCF)

According to Alves (2010), the basic principle of a DCF (8) model is that the value of the asset is the value of its future cash flows brought to present value at a discount rate.

$$\text{Value} = \frac{FC_t}{(1+n)^t} \qquad (8)$$

Where n is the life of the asset, FCt is the cash flow in period t and r is the discount rate that reflects the risk of the estimated cash flows. There are basically three different types of cash flow models. The first evaluates only the part of the shareholder or investor in the asset, the second evaluates the company as a whole and the third evaluates the company in pieces, beginning with its operations and adding the effects of debt and other participations. Although the three types discourage cash flows, the relevant cash flows and discount rates are different for each of them and general (Alves, 2010).

3.17 Considerations

Investment decisions cannot be made on the basis of just one method or tool because each of the different methods presented provides different sets of relevant information. Discounted payback and payback offer both a risk and liquidity indicator. The net present value (NPV) provides a direct measure of the project's benefits to shareholders. The IRR provides information on the investment safety margin (Brigman, 2001).

According to Makaron (2012), in the initial phase, at the time of project planning, the main financial indicators of the project related to the final product are defined, such as predictions of return on investment, Net Present Value (NPV), the Internal Rate of Return (IRR), the Payback Method, and the expected cash flow with the new product.

It is necessary to carry out a periodic review of this analysis throughout the project, since preliminary information is available at the Project Planning stage and subject to change. As development phases occur, the economic-financial feasibility analysis can be refined and compared with the initially planned one.

The review of economic-financial viability should occur at the end of each of the phases of project development. Also, it can occur at any time when major changes are demanded of the project, whether motivated by internal factors or external factors, not manageable by the entrepreneurs. The constant review is intended to verify whether the project will remain financially viable or not.

3.18 Project Risks

Borges et al. (2005) classify risks for projects as follows: 1) implementation risks; 2) political risk, related to country risk, as well as legal and environmental risk; 3) commercial risk; 4) currency risk and other financial risks; 5) Acts of God and force majeure.

Implementation risks are considered to be the most relevant because they deal with one of the most critical and comprehensive stages of the project. In this way, implementation risks have subdivisions that are: project risk, hydrological risk and construction risk (Siffert Filho et al., 2009).

The project risk in the construction of a hydroelectric plant consists in the increase of the excavations for the construction of the dam due to the presence of some material different from those predicted in the geological survey (Faria, 2003).

According to Makaron (2012), both project and hydrological risks can be mitigated through the hiring of consultancies and engineering companies experienced in the subject and with the special attention that must be given to the data collection of the region.

With regard to political risk, the major concerns of the entrepreneur are the stability and applicability issues of the legislation. The risk of legislation can be defined with the consolidation and maturity of the Brazilian Judicial System, in order to ensure that contracts are executed (Borges et al., 2005). In addition, it is important that there is credibility in the continuity of the current rules of the sector, without radical changes that could make unfeasible projects already started.

Also, private entrepreneurs in Brazil should consider in the analysis the bureaucratic-regulatory risk faced in the authorization process for the exploration of potentials.

Among the political aspects, in the specific case of Brazil, another aspect of great relevance is the environmental issue. It represents a risk of significant impact, either due to the increase in environmental compensation costs, due to delayed schedules due to problems obtaining environmental licenses, or even conflicts with environmental entities and social communities (Makaron, 2012).

According to Siffert Filho et al. (2009), commercial risk is related to the change in the variables that will determine the future cash flows: demand and price. This risk is not significant in the Brazilian market. On the other hand, financial risk can be defined as the impact generated by the increase in financial costs due to the separation between the index of financing and inflation.

And lastly, there are risks - fortuitous and force majeure - that can have natural causes (floods, hurricanes, fires ...), acts of men (wars, strikes ...), governments (declaration of the state of site or curfew) or impersonal (global economic crisis).

3.19 Summary and Conclusions

This chapter addressed the technical concepts needed to prepare a model for the economic and financial evaluation of a Mini Hydropower plant implementation project. It was verified in this chapter that investors, when evaluating a project, seek the minimum cash generation to remunerate the opportunity cost for the investment risk.

The financial indexes are of great importance in the decision process: Payback (simple and discounted); Net present value, and internal rate of return. Other concepts related to economic viability were described too.

The assumptions that compose the projection of the cash flow in a Mini Hydropower project and the adequacy and care in the choice of variables were analyzed. These components were subdivided into: Estimate of Revenue; Transmission line; Financing; Depreciation. It was observed that this detailing of assumptions is fundamental, because if the values adopted are overestimated or underestimated, they can generate distortions that will be perceived in the project implementation phase.

Finally, with respect to the risks of the project, it was observed that the most critical categories that cause the greatest impact on the return of a project in this segment are: implementation risks, in terms of design, hydrology and construction and the risks with respect to legal and environmental aspects. Implantation risks directly impact the increase in costs, due to a delay in the schedule, and may arise from the technical commitment of the projects, creating future needs for repair investments.

Chapter 4

Case study

This chapter presents the case study of economic feasibility analysis for the implementation of a Mini Hydro Powerplant. The financial modeling assumptions and rules presented in chapters 2 and 3 are applied.

4.1 Introduction

In order to analyze the economic and financial viability of the implementation of a Mini Hydropower, the Case Study method was chosen because it is a research tool that reports on organizational practices or offers policy alternatives for companies. In order for the objective of this work to be achieved, a few steps were followed:

Firstly, a detailed study of the electric power sector was carried out, as well as the Mini Hydropower sector. Then, through studies made by the company and the history of other works of the same size, the necessary investments were estimated. This point is of great importance for the feasibility analysis of the project and has therefore been treated in detail.

The third step was to estimate the costs and expenses that the enterprise will have in the course of its commercial operation. We have also studied ways of financing and using third-party capital for this type of venture, noting the advantages and disadvantages of using debt. Next, revenues were projected, which are fixed - in most cases, and indexed to an inflation index.

In this way, it was possible to make financial projections and evaluate the project according to the various investment assessment methods seen in the theoretical review. At the end of the study, it was concluded the best investment decision to be made, accepting or rejecting the project; making available to the interested investor sufficient information so that its decision is made with the greatest security and accuracy possible.

4.2 Project description

The project will be built in the northern region of the state of Santa Catarina, in the southern region of Brazil. It is located at river Itapocu, in the border of the municipalities of Guaramirim (right bank) and Araquari (left bank). A drop in the river will be used. The image of the Mini Hydropower installation site can be seen in Figure 4.1.

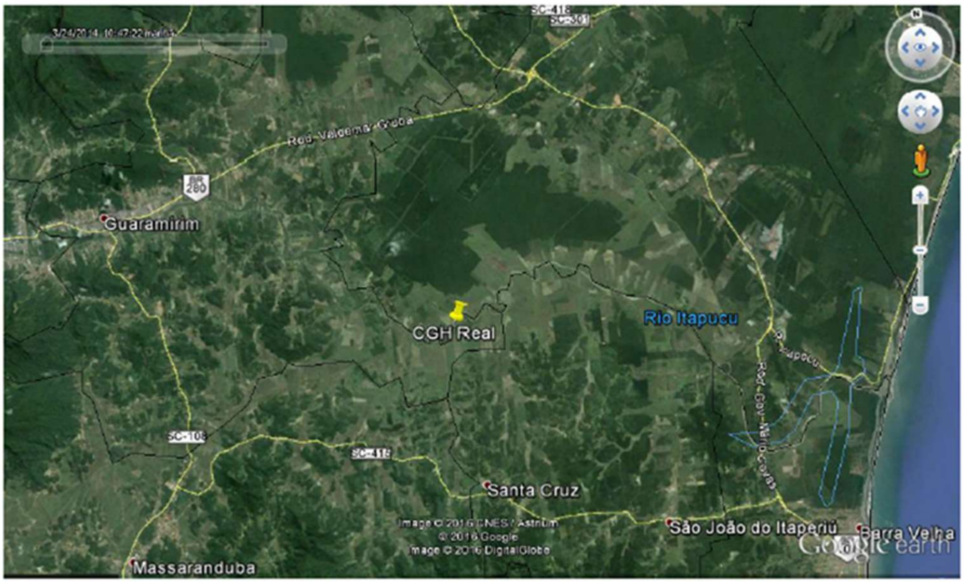

Figure 4.1: Location of Mini Hydropower plant (Google Earth, 2017)

4.2.1. Hydrographic basin

The Mini Hydropower plant under study is located in the Atlantic basin, Strait - 8, sub - basin 82, in the Itapocu River. The Itapocu River is wholly in the state of Santa Catarina. It is formed from the junction of the Rio Novo and the Humboldt River in the urban center of the city of Corupá and, running from west to east, also bathes the municipalities of Jaraguá do Sul and Guaramirim, site of Mini Hydropower plant, flowing into the Atlantic Ocean. Its main tributaries are: Piraí river, Itapocuzinho river and Jaraguá river.

4.2.2 Hydrologic Studies

The hydrological studies performed for the Mini Hydropower plant site follow the basic assumptions recommended in the ANEEL Guidelines and Eletrobrás manuals, in accordance with the data available in the sub-basin under study.

The hydrological data of the Itapocu river, used in this work, were taken from the hydrological study available in the simplified hydroelectric inventory of the Itapocu river. This inventory was made to select the most favorable use for the construction of the Mini Hydropower.

The water catchment area of the Itapocu River to the site of Mini Hydropower plant presented a drainage area of 2,040.00 km². Figure 4.2 shows the Mini Hydropower plant drainage area under study.

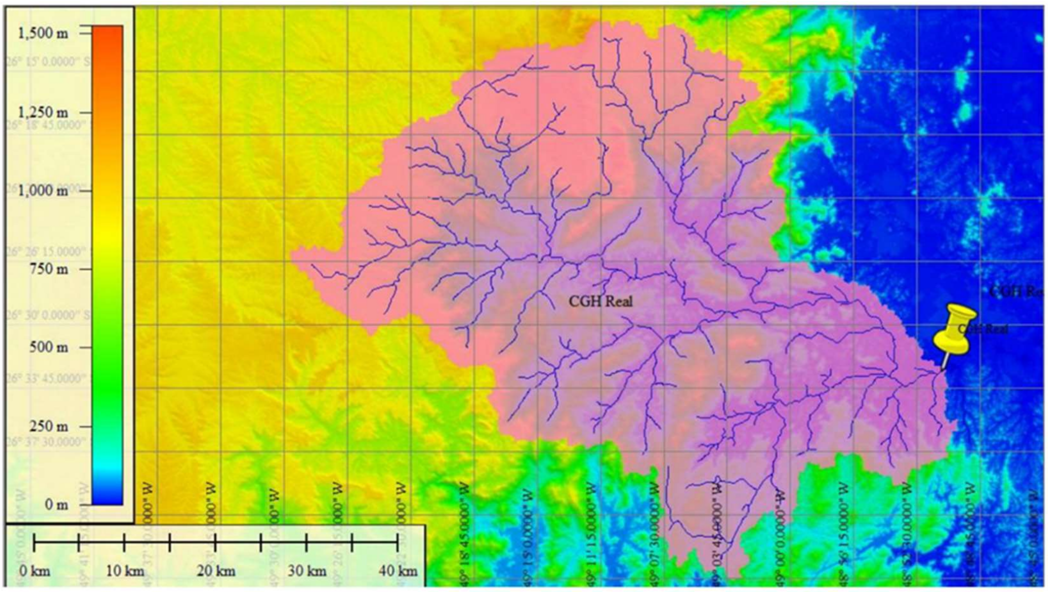

Figure 4.2: Mini Hydropower plant drainage area

4.2.3 Flow Analysis

For the hydrological survey, the fluviometric stations of the region, near the study site of sub-basin 82, were studied, with a drainage area compatible with the study site and data available for a survey of mean flow rates at the site.

After consulting the stations included in the Aneel fluviometric bulletin, and analyzing rigorous criteria, the Jaraguá do Sul Post was selected (82350000). This Post presented a good database for use in this project, with a Drainage Area compatible. It is located on the Itapocu River, in the municipality of Jaraguá do Sul, Santa Catarina, approximately 23.5 km from the Mini Hydropower plant.

In this way, the average flow (mlt) of the study site was estimated through the relation of the drainage area and average flow of the related station. The average flow rate was 53.46 m^3 / s.

4.2.4 Permanence Curve

The permanence curve relates the flow of the river to the time when a given flow equals a given value. For the elaboration of the permanence curve, the data were organized in order to establish a cumulative relative frequency. From these data is established a probability of occurrence of flows. A better visualization and interpretation of these data is done by observing the graph in which the flows and the frequencies with which they occur are represented (the so-called flow continuity curve).

The graph shows the continuity curve of the mean daily flows to the base station site, as well as to the axis of the Mini Hydropower plant utilization (Figure 4.3).

Área de drenagem = 2040,00 km^2

Q (mlt) = 53,46 m^3/s – vazão media

Drainage area = 2040.00 km^2

Q (mlt) = 53.46 m^3 / s - average flow

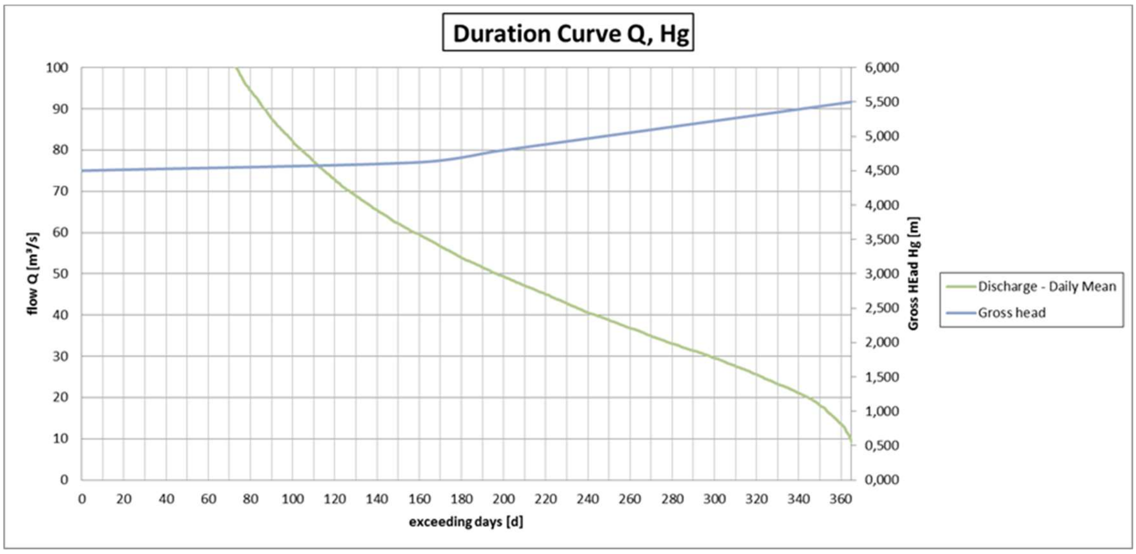

Figure 4.3: Curve of permanence of the average monthly flows

The nominal gross fall for the project was determined by topographical measurement of the site of the project. The nominal gross fall of the project is H = 4.15 m and maximum gross fall is 5.5 m, according to figure 4.3.

4.2.5 Installed Power Calculation

With the values of the useful fall and the river flow, we have the necessary inputs to carry out the calculation of the installed power of the case study. According to Eletrobrás, the calculation of the installed power of a Hydroelectric Plant consists of the following formula:

$$P = g * Q * Hu * nt \tag{9}$$

with:

P = Installed power (W);

Q = flow (m^3 / s);

Hu = useful height (m);

g = specific weight of water (N / m^3);

ɳt = turbine-generator efficiency

Thus, using the measurements performed at the site of the hydroelectric project in question, the values shown in Table 4.1 below were obtained.

Total Flow (m^3/s)	53.46
Height (meters)	5.5
Total income of the set	0.7
Specific weight of water (kg/m^3)	1000
Gravity (m/s^2)	9.81
Power (in kW)	2,019

Table 4.1: Data for power calculation

The efficiency of the turbine-generator set used is based on studies done to calculate the power of the Screw turbine. Recent research in commercial installations of Screw Turbines in Europe, developed by Hawle et al. (2012), an average operating efficiency of 69% was found, and maximum efficiencies greater than 75% were found for this type of system.

According to the presented formula (9), a value of 2,019 kW is reached for the estimated power of the Mini Hydropower plant, as described in Table 4.1.

4.2.6 Annual energy generation

Based on the research carried out and according to catalogs of the existing suppliers, it is observed that the ideal unit flow cannot exceed the value of $10m^3$ / s. This is characterized by the constructive limitation of the external diameter of the Screw turbine.

The graph below (Figure 4.4) exemplifies the operational field of a Screw turbine and its basic characteristics, as a relation between fall, flow, power and external diameter of the equipment.

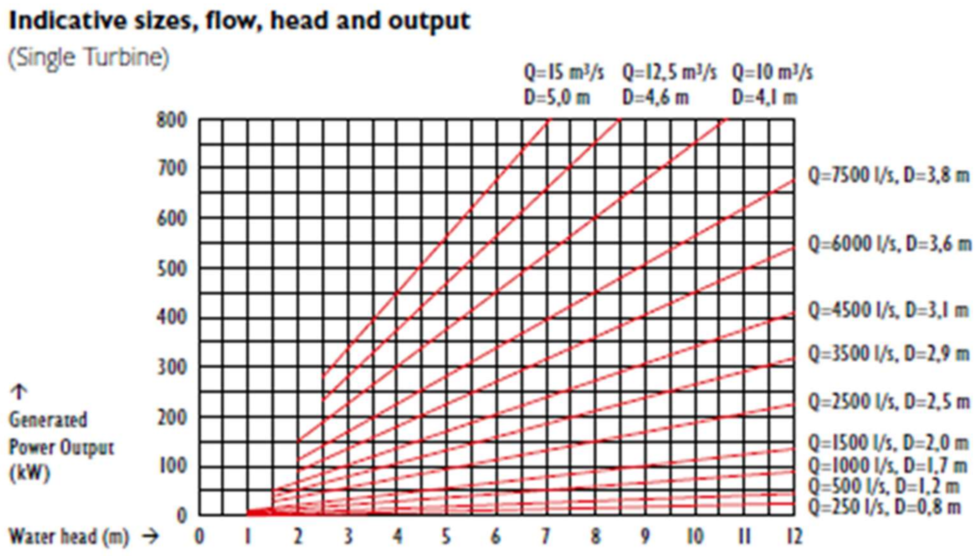

Figure 4.4: Data indicative of Screw turbine (Spaans Babcock, 2016)

Based on the flow curve of the project, it was defined that 6 machines will be used, thus establishing the flow curve in 170 days, according to figure 4.5. The unit flow rate of Q = 9m³ / s was obtained by dividing the average flow rate (Q (mlt) = 53.46 m³ /s) by the number of machines to be installed (6 units).

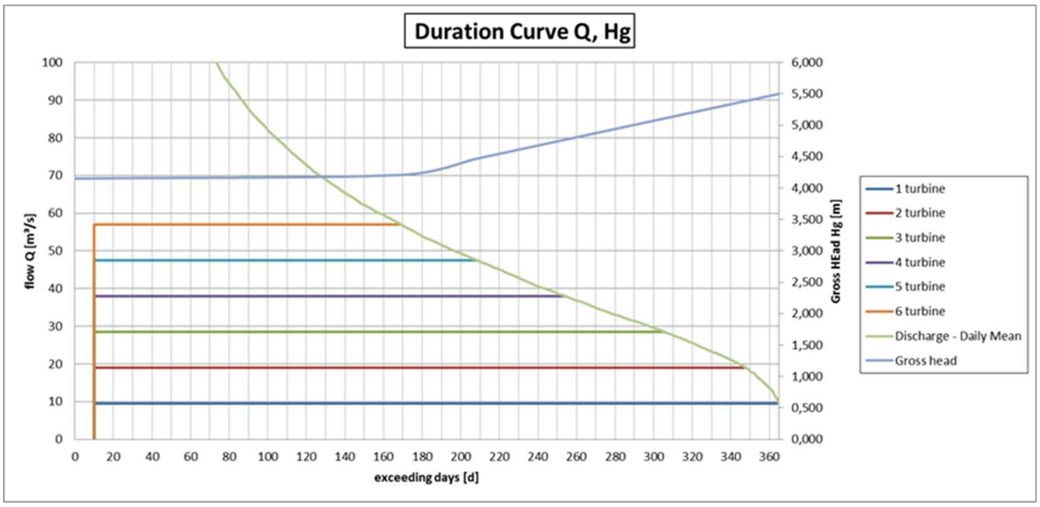

Figure 4.5: Number of Mini Hydropower plant machines

The estimated annual energy generation can be seen in Table 4.2.

turbine	flow	days	op d	height	power (kW)	work (MWh)	Σwork (MWh)
1	9	365.0	355.0	5.5	339.9	2896.1	2896.1
2	18	350.3	340.3	5.4	334.7	2792.5	5688.6
3	27	313.0	303.0	5.2	321.5	2481.6	8170.2
4	36	264.9	254.9	4.9	304.4	2037.5	10207.7
5	45	220.1	210.1	4.7	288.5	1609.5	11817.2
6	54	179.6	169.6	4.4	274.1	1249.0	13066.2

Table 4.2: Annual energy generation

4.4 Economic Viability Analysis

4.4.1 Unrecoverable Costs

According to the bibliography consulted, unrecoverable costs are the resources applied in the study phase of the project, which are fundamental for decision making. For a Mini Hydropower project these expenses are significant, since the enterprise that arises has a high value. The table below shows the estimated accounts and values:

Prospection	R$ 60.000
Topography	R$ 45.000
Basic project	R$ 200.000
Hydrological studies	R$ 40.000
Environmental assessment	R$ 20.000
Licensing	R$ 50.000
Unrecoverable costs	**R$ 415.000**

Table 4.3: Unrecoverable Costs

4.4.2 Initial Investment Estimate

After spending on exploration, investment analysis and obtaining licenses, there are investments that will make Mini Hydropower effectively become a venture.

For the development of this work, data based on sources from the entrepreneur, companies and suppliers were used, as well as sources for consultations, such as the Guidelines for Small Hydroelectric Power Plant Studies and Projects. (Eletrobrás, 2000) and the Manual of Procedures for Small Hydroelectric Power Plants Basic Design of Mini and Small Hydroelectric Plants (CERPCH).

The costs for implementing a project must be calculated according to the reality of the installation site and taking into account its peculiarities. To define the total amount used as Initial Investment, it was necessary to define pre-operating expenses, investments in fixed assets and initial working capital.

The Table 4.4 below shows the expectation that each item generates in the total cost of the project. It is noted that the civil works together with the acquisition of the permanent equipment represent approximately two thirds of the total expenses. Thus, using this perspective and taking into account the simplicity and peculiarities of the project, a price estimate will be raised for the main expenses in order to calculate the period of return of the project with the profits coming from the commercialization of energy.

Description	Cost (%)
Initial Studies	
Site Investigation	1.0%
Hydrological study	0.5%
Environmental assessment	1.0%
Basic project	1.0%
Estimated costs	0.3%
Preparing Reports	0.2%
Project management	1.0%
Tickets and daily	0.6%
Development	
PPA negotiation	0.5%
Licenses	0.5%
Geological Survey	0.6%
Project management	0.7%
Tickets and daily	0.6%
Engineering	
Executive project	3.0%
Contracting services	1.0%
Construction Supervision	3.0%
Generation equipment	
Turbines, generators and panels	22.0%
Installation	3.0%
Transport	2.0%
Other Structures	
Access Entry	5.0%
Dam	9.0%
Adduction channel	4.0%
Water inlet	2.0%
Machine House	3.0%
Substation and Transmission lines	10.0%
Transport	2.0%
Miscellaneous	
Contractor overhead	5.0%
Training	0.5%
Contingencies	12.0%

Table 4.4: Estimation of Costs for Implementation of a Mini Hydropower plant (CERPH, 2016)

For the calculation of the initial investment, the estimated amount of R$ 5,500 / kW installed (Fgv, 2011) will be used, which is the amount usually used to estimate the cost of building a Mini Hydropower. Therefore, since the installed power of the previously calculated plant is 2.000 kW, the estimated total value of a new construction is:

Total investment value = 2.000 kW x R$ 5.500 / kW = R$ 11,000,000.00

Table 4.5 below shows the estimate for the main project expenses, which were made according to the multiplication of the total cost of installing a new plant, by the percentage that each component absorbs according to Table 4.4.

Description	Cost (%)	Estimated Cost (R$)
Initial Studies		
Site Investigation	1.0%	R$ 110,000.00
Hydrological study	0.5%	R$ 55,000.00
Environmental assessment	1.0%	R$ 110,000.00
Basic project	1.0%	R$ 110,000.00
Estimated costs	0.3%	R$ 33,000.00
Preparing Reports	0.2%	R$ 22,000.00
Project management	1.0%	R$ 110,000.00
Tickets and daily	0.6%	R$ 66,000.00
Development		
PPA negotiation	0.5%	R$ 55,000.00
Geological Survey	0.6%	R$ 66,000.00
Project management	0.7%	R$ 77,000.00
Tickets and daily	0.6%	R$ 66,000.00
Engineering		
Executive project	3.0%	R$ 330,000.00
Contracting services	1.0%	R$ 110,000.00
Construction Supervision	3.0%	R$ 330,000.00
Generation equipment		
Turbines, generators and panels	22.0%	R$ 2,420,000.00
Installation	3.0%	R$ 330,000.00
Transport	2.0%	R$ 220,000.00
Other Structures		
Access Entry	5.0%	R$ 550,000.00
Dam	9.0%	R$ 990,000.00
Adduction channel	4.0%	R$ 440,000.00
Water inlet	2.0%	R$ 220,000.00
Machine House	3.0%	R$ 330,000.00
Substation and Transmission lines	10.0%	R$ 1,100,000.00
Transport	2.0%	R$ 220,000.00
Miscellaneous		
Contractor overhead	5.0%	R$ 550,000.00
Training	0.5%	R$ 55,000.00
Contingencies	12.0%	R$ 1,320,000.00
Total		**R$ 10,395,000.00**

Table 4.5: Cost Estimated of Required Components

It can be seen from Figure 4.10 above that according to the calculations made, the final investment value that will be required to be made for the Mini Hydropower deployment is R$ 10,395,000.00.

4.4.3 Investment Financing

The feasibility study considers that the capital financing for the initial investment will be made by the National Development Bank (BNDES), which represents a traditional partner of infrastructure entrepreneurs.

According to the BNDES, the option of financial support that fits the business here proposed is the BNDES Finame PSI Capital Goods Program - MPME. For this type of financial support, the following conditions apply:

- Total financing term: up to 120 months (the total term includes grace periods and amortization periods), ie 10 years;
- Maximum grace period: 24 months;
- Interest rate: fixed at 3.5% per year, including the remuneration of the accredited financial institution;
- BNDES participation: up to 100% of the eligible items.

As this line of financing covers the acquisition of machinery and equipment, in addition to working capital, it was necessary to carry out a survey of the eligible items among the items listed in Table 4.4 for the initial investment. These items can be seen in Table 4.6 below.

Description	Value	Item financeable?
Generating equipment		
Turbines, generators and panels	R$ 2,420,000.00	Yes
Installation	R$ 330,000.00	No
Transport	R$ 220,000.00	No
Other Structures		
Machine House	R$ 330,000.00	Yes
Substation and Transmission lines	R$ 1,100,000.00	Yes
Transport	R$ 220,000.00	No
Miscellaneous		
Contingencies	R$ 1,320,000.00	Yes
Contractor overhead	R$ 550,000.00	Yes
Training	R$ 55,000.00	No
Total Cost of Initial Investment	**R$ 10,395,000.00**	
Items financiables	**R$ 6,545,000.00**	
Financeable percentage	**63.0%**	

Table 4.6: Financing Items

Usually, within the grace, interest is charged on the balance due. The amortization period is the period beginning immediately after the grace period ends, when the payment of the principal of the resources contracted in the financing begins, plus the portion of capitalized charges, when applicable. During the amortization period, a portion of the principal is paid periodically, plus capitalizations made, plus the interest rate on the debtor balance of the transaction. This periodicity is usually monthly. Some Funding Programs may be quarterly or semi-annual. In general, BNDES uses the Constant Amortization System (SAC).

Total investment	R$ 10,395,000.00
Participation of BNDES	63.0%
BNDES financing	R$ 6,545,000.00
Time (years)	10
Grace period (years)	2
Interest rate (year)	3.5%
Inflation rate	4.5%
Loan term (years)	8

Period	Year 0	Year 1	Year 2	Year 3	Year 4
Year	2018	2019	2020	2021	2022
Inicial balance	R$ 6,545,000.00	R$ 6,545,000.00	R$ 6,545,000.00	R$ 5,726,875.00	R$ 4,908,750.00
Provision	R$ -	R$ -	R$ 1,341,725.00	R$ 1,276,275.00	R$ 1,210,825.00
Interest	R$ 229,075.00	R$ 523,600.00	R$ 523,600.00	R$ 458,150.00	R$ 392,700.00
Amortization	R$ -	R$ -	R$ 818,125.00	R$ 818,125.00	R$ 818,125.00
Final balance	**R$ 6,545,000.00**	**R$ 6,545,000.00**	**R$ 5,726,875.00**	**R$ 4,908,750.00**	**R$ 4,090,625.00**
Period	Year 5	Year 6	Year 7	Year 8	Year 9
Year	2023	2024	2025	2026	2027
Inicial balance	R$ 4,090,625.00	R$ 3,272,500.00	R$ 2,454,375.00	R$ 1,636,250.00	R$ 818,125.00
Provision	R$ 1,145,375.00	R$ 1,079,925.00	R$ 1,014,475.00	R$ 949,025.00	R$ 883,575.00
Interest	R$ 327,250.00	R$ 261,800.00	R$ 196,350.00	R$ 130,900.00	R$ 65,450.00
Amortization	R$ 818,125.00	R$ 818,125.00	R$ 818,125.00	R$ 818,125.00	R$ 818,125.00
Final balance	**R$ 3,272,500.00**	**R$ 2,454,375.00**	**R$ 1,636,250.00**	**R$ 818,125.00**	R$ -

Table 4.7: Breakdown of BNDES financing: Constant Amortization System

The inflation rate used is based on the annual inflation target set by the Central Bank of Brazil and corrects interest annually. Since 2005, the stipulated target is 4.5% per year, as specified in the Table above.

4.5 Inicial Working Capital

The contingency reserve, defined as 12% of the total initial planned investments, serves to reduce the risk of the work if it requires a greater capital contribution than planned and to be the initial working capital amount of the enterprise. In this Case Study, the Initial Working Capital used was R$ 1,247,400.00.

4.6 Development of the Statement of the Year Result

With the calculation of the initial investment required and the financing to be carried out, we can elaborate the forecasts of the Development of the Statement of Income for the Year of the enterprise over the years. The income statement for the year will compare revenues, costs and results according to the accounting principle in order to show the formation of net profit or loss in a given year. Its elaboration will follow the order shown in Table 4.8 below:

Development of the Statement of Income for the Year				
Period				
Year				
Gross Revenue				
Revenue from energy sales				
Sales Taxes				
ISS				
PIS/COFINS				
Net Revenue				
Operational costs				
Operation and maintenance costs				
Rate of Use of the Transmission System				
Inspection Fee for Electric Energy Services				
Gross Operating profit				
Gross margin (%)				
SG&A				
General and Administrative Expenses				
Insurance				
EBITDA				
% EBITDA				
Depreciation				
Financial expenses				
Interest				
LAIR				
IR + CSLL				
Net profit				
% Net profit				

Table 4.8: Items to be considered in the Development of the Statement of Income for the Year

At the end, net income will be used as input for the preparation of the cash flow and the economic analysis itself.

4.6.1 Estimate of Gross Revenue

As discussed in Chapter 3, for the calculation of the sale of energy generated by Mini Hydropower plant under study, the Reference Value of R$ 141.72 per MWh for the year 2012, published by ANEEL, will be used. In the analysis and economic projection made, this value will also suffer an annual adjustment based on the inflation rate, set by the Central Bank, whose target for the years 2017, 2018 and 2019 is 4.5%. This rate will be maintained for the entire planning horizon to readjust the sales value of MWh.

In the present case study, it was decided to sell all the energy generated, without having its own consumption. This is because in the land where the Mini Hydropower plant is located, there is no housing or commercial or agricultural establishment and, therefore, there is no demand for electricity consumption by the producer. There is only a small portion of the energy needed to maintain Mini Hydro's structure, with little representativeness in total energy production.

The total term of implementation of a Mini Hydropower plant is estimated to last one year. Therefore, the revenue from the generation of energy will only be considered from "year one" (first year of the plant in operation) within the horizon studied as per Table 4.9.

Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Year	2018	2019	2020	2021	2022	2023	2024
Total Annual Production (MW.h)	0	13,066.2	13,066.2	13,066.2	13,066.2	13,066.2	13,066.2
Price for MW.h (R$)	141.72	148.10	154.76	161.73	169.00	176.61	184.56
Total revenue (R$)	**0**	**1,935,076**	**2,022,154**	**2,113,151**	**2,208,243**	**2,307,614**	**2,411,456**

Period	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Year	2024	2025	2026	2027	2028	2029	2030
Total Annual Production (MW.h)	13,066.2	13,066.2	13,066.2	13,066.2	13,066.2	13,066.2	13,066.2
Price for MW.h (R$)	184.56	192.86	201.54	210.61	220.09	229.99	240.34
Total revenue (R$)	**2,411,456**	**2,519,972**	**2,633,371**	**2,751,872**	**2,875,707**	**3,005,113**	**3,140,344**

Table 4.9: Total revenue Calculation

4.6.2 Taxes and charges

Regarding the gross revenue of a Mini Hydropower plant business, the main taxes levied are: the inspection fee for electric energy services, ICMS, PIS, COFINS and transmission charge. On income after operating expenses and costs of products sold, income tax and social contribution on net income (Alves, 2010).

For the development of this work we used Presumed profit considering that the calculation basis (8% in the case of corporate income tax) will be lower than the operating profit. The taxation applied in the case study considering Presumed Profit will be:

a) ISS

According to Mancebo (2013) on the power generation service, should be taxed on services of any kind (ISS), a municipal tax. For the purpose of economic evaluation, the maximum rate predicted by the federal government was used: 5% of gross revenue.

b) PIS / COFINS

According to Alves (2010), private sector legal entities, including service providers, public companies and mixed-capital companies, contribute to PIS. From Law 9.718 / 98, the basis of calculation of the contribution is the totality of the revenues earned by the legal entity, being irrelevant the type of activity exercised. In the case of electricity generation, PIS is 0.65% of gross revenue.

The contribution to social security financing (COFINS) is also governed by Law 9.718 / 98, and the legal entities in private law are taxpayers. The calculation base is also the total revenue earned by the legal entity and its rate is 3.00% of gross revenue.

Therefore, by adding the rates, the taxation of PIS / COFINS is 3.65% over gross revenue.

c) Corporate Income Tax (IRPJ) and Social Contribution on Net Income (CSLL):

The social contribution on net income is calculated based on the amount of income for the year before the provision for income tax. Taxes on corporate income are determined quarterly.

In the presumed profit regime, we have:

- Presumed profit for services in general is 32% on gross revenue;
- Income Tax of 15%;
- CSLL of 9%;
- IR + CSLL = 32% x (15% + 9%) = 7.68%

4.6.3 Operational costs

a) Operation and Maintenance

The cost of Operation and Maintenance for the new venture must be calculated based on the characteristics of the equipment, consumables, maintenance labor and the type of operation, local or remote, as the case may be (Candido, 2012). The estimated value of 7.5% of revenue for the operation and maintenance of the Mini Hydropower plant under study.

b) Rate of Use of the Transmission System - TUST

As already mentioned in chapter 3, the average value of TUST applied by Eletrosul, the concessionaire operating in the region where the Mini Hydropower plant is located, is R$ 4.20 per kW.m. for the tip and 2.09 per kW.m. for considering the discounts provided by Normative Resolution No. 77, which provides for a reduction of at least 50% in the tariffs for the use of transmission systems - TUST and TUSD for hydroelectric projects with a power of 3 MW or less.

Of the hours worked each day, 1/8 (12.5%) of the time is considered as production at the tip and the other 7/8 (87.5%) are considered as out of point. Thus, for the calculation of the annual cost of using the transmission system, the weighted average of the values presented above was used.

c) Rate of Inspection of Electric Energy Services - TFSEE

As described in the Chapter 3, the calculation formula of the Rate of Inspection of Electric Energy Services for the self-producers, independent producers of electricity and generation consortia, according to ANEEL (Technical Note 11/2013-SRE / ANEEL):

TFape/pie = 0,4% x (BETU x P)

The annual value of the annual benefit derived from the exploration (typical unit economic benefit - BETU) of the energy generation activity for the year 2013 was stipulated at R$ 484.21 per KW, according to dispatch no. 001/2013-SRE / ANEEL. However, as it was assumed that the plant would begin operating in the coming years, it is necessary to project the growth of this rate from the historical basis presented in Table 4.10.

For the year 2017, the expected value of the operating rate is R$ 769.94 / kW, obtained by multiplying the benefit rate resulting from the exploration of the generation activity in the year of 2013 by the historical average rate growth, resulting in at a value for the inspection fee of 2.12 R$ / KW. In the present case study, the installed power is equivalent to 2000KW, the amount to be paid would be approximately R$ 6104.32 in the year 2018.

For the following years, the nominal efficiency loss of the panels (the rate of 0.896% per year) in the calculation of the installed power is considered, as can be seen in Table 4.11. For the economic analysis, an annual rate of BETU, of 9.72% per year.

Reference Year	Fee charged for the Exploration Benefit (R$/KW)
2008	303.78
2009	335.42
2010	363.60
2011	385.73
2012	418.39
2013	484.21
Cumulative average growth rate (% per year)	9.72%

Table 4.10: Evolution of the growth of the exploration rate charged

Year	Installed Power (KW) - (Loss of Efficiency of 0.896% per year)	Projection of the Exploration rate of Electricity Generation (9.72% annually)	Rate of Inspection of Electric Energy (0.4% * KW * Exploration Fee)
0	2,000	701.73	5,613.84
1	1,982.08	769.94	6,104.32
2	1,964.32	844.78	6,637.64
3	1,946.72	926.89	7,217.57
4	1,929.28	1,016.98	7,848.16
5	1,911.99	1,115.83	8,533.85
6	1,894.86	1,224.29	9,279.44
7	1,877.88	1,343.29	10,090.18
8	1,861.06	1,473.86	10,971.75
9	1,844.38	1,617.12	11,930.34
10	1,827.86	1,774.30	12,972.68

Table 4.11: Projection of Rate of Inspection of Electric Energy Services annual payments

4.6.4 Annual Direct Expenditures

a) General and administrative expenses

General and administrative expenses of a Mini Hydropower plant can be estimated at 3.5% of gross revenue (Mancebo, 2013).

b) Insurance

As discussed in the Chapter 3, it is very important to contract the insurance to cover operational risks / loss of profit that will ensure the entrepreneur against any damage caused by the stoppage of the operation of the plant. Another insurance that must be contracted is the civil liability insurance, which will ensure the entrepreneur against third parties (Gouvea, 2012). For the case studied, insurance expense represents 1.5% of revenue.

4.6.5 Depreciation of assets

The depreciation term is applied to purchased equipment and constructed structures that may be depreciated in accordance with applicable law. The annual depreciation rate of each of the items broken down in Table 4.12 was based on the Economic Useful Life and Depreciation Rate Study (ANEEL, 2000). Next, the annual depreciation charge is calculated, based on the linear depreciation method, where the total depreciation charge will be distributed equally over the years for each item. It should be taken into account that the deadline for Mini Hydropower plant's start-up is one year, due to the deadline for the installation of the equipment and construction of the missing structures. Therefore, depreciation rates in year zero will not be considered.

	Value	Annual Depreciation (%)	Term (years)	Annual Depreciation (R$)
Turbines, generators, panels	R$ 2,420,000.00	2.5%	40	R$ 60,500.00
Machine House	R$ 330,000.00	2.0%	50	R$ 6,600.00
Substation and Transmission lines	R$ 1,100,000.00	5.0%	20	R$ 55,000.00
				R$ 122,100.00

Table 4.12: Depreciation calculation

4.6.6 Bank interest rate

The interest rate to be used in this Case Study is the fixed amount of 3.5% per annum of the BNDES, including the remuneration of the accredited financial institution. The amount is charged to the debit balance and already begins to be discounted from the year "zero", even with the project still in the pre-operation phase.

4.7 Development of the Statement of Income for the Year

After analyzing each item that composes the Development of the Statement of Income for the Year, a summary of the calculations used in each of them will be demonstrated in Table 4.13 below.

Development of the Statement of Income for the Year	Calculation Formula
Gross Revenue	**Same as "Revenue from Energy Sales"**
Revenue from energy sales	Total annual energy production x energy price in the year in question
Sales Taxes	**ISS + PIS/COFINS**
ISS	5% of Gross Revenue
PIS/COFINS	3.65% of Gross Revenue
Net Revenue	**Gross Revenue - Sales Taxes**
Operational costs	**Operation and Maintenance + Rate of use of the transmission + Inspection Fee**
Operation and maintenance costs	7.5% of Gross Revenue
Rate of Use of the Transmission System	Weighted average of the values at the tip and off the tip x annual energy production
Inspection Fee for Electric Energy Services	0.4% x (BETU x Installed Power) x Inflation
Gross Operating profit	**Net Revenue - Operational costs**
Gross margin (%)	Gross Operating Profit / Net Revenue
SG&A	**General and Administrative Expenses + Insurance**
General and Administrative Expenses	3.5% of Gross Revenue
Insurance	1,5% of Gross Revenue
EBITDA	**Gross Operating Profit - SG&A**
% EBITDA	EBITDA / Net Revenue
Depreciation	**Value depreciated by Mini Hydro power components**
Financial expenses	**Same as "Interest"**
Interest	3.5% of the Debtor Balance
LAIR	**EBITDA - Depreciation - Financial Expenses**
IR + CSLL	Gross Revenue x 32% x (9% + 15%)
Net profit	**LAIR - (IR + CSLL)**
% Net profit	Net Income / Net Revenue

Table 4.13: Development of the Statement of Income for the Year Calculation Formula

With the calculation formulas used to prepare the Development of the Statement of Income for the Year presented, we will see below the statement of income for the year forecast for the business (Tables 4.14 and 4.15).

Development of the Statement of Income for the Year						
Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Year	2018	2019	2020	2021	2022	2023
Gross Revenue	0.00	1,935,076	2,318,270	2,422,592	2,531,608	2,645,531
Revenue from energy sales	0.00	1,935,076	2,318,270	2,422,592	2,531,608	2,645,531
Sales Taxes	0.00	167,384.05	200,530	209,554.19	218,984	228,838.41
ISS	0.00	96,754	115,913	121,130	126,580	132,277
PIS/COFINS	0.00	70,630	84,617	88,425	92,404	96,562
Net Revenue	0.00	1,767,692	2,117,739	2,213,038	2,312,624	2,416,692
Operational costs	0.00	186,495	215,768	224,172	232,979	242,209
Operation and maintenance costs	0.00	145,131	173,870	181,694	189,871	198,415
Rate of Use of the Transmission System	0.00	35,260.48	35,260.48	35,260.48	35,260.48	35,260.48
Inspection Fee for Electric Energy Services	0.00	6,104.32	6,637.64	7,217.57	7,848.16	8,533.85
Gross Operating profit	0.00	1,581,196	1,901,971	1,988,865	2,079,645	2,174,483
Gross margin (%)	0.00	89.45%	89.81%	89.87%	89.93%	89.98%
SG&A	0.00	96,753.79	115,913.48	121,129.59	126,580.42	132,276.54
General and Administrative Expenses	0.00	67,727.65	81,139.44	84,790.71	88,606.29	92,593.58
Insurance	0.00	29,026.14	34,774.04	36,338.88	37,974.13	39,682.96
EBITDA	0.00	1,484,442	1,786,057	1,867,736	1,953,065	2,042,207
% EBITDA	0.00	84.0%	84.3%	84.4%	84.5%	84.5%
Depreciation	0.00	122,100.00	122,100.00	122,100.00	122,100.00	122,100.00
Financial expenses	229,075.00	523,600.00	523,600.00	458,150.00	392,700.00	327,250.00
Interest	229,075.00	523,600.00	523,600.00	458,150.00	392,700.00	327,250.00
LAIR	229,075.00	838,742	1,140,357	1,287,486	1,438,265	1,592,857
IR + CSLL	0.00	148,613.81	178,043.11	186,055.05	194,427.52	203,176.76
Net profit	229,075.00	690,128.6	962,314.4	1,101,430.5	1,243,837.0	1,389,679.9
% Net profit	-	39.04%	45.44%	49.77%	53.78%	57.50%

Table 4.14: Development of the Statement of Income for the Year (Year 0 to Year 5)

Development of the Statement of Income for the Year					
Period	Year 6	Year 7	Year 8	Year 9	Year 10
Year	2024	2025	2026	2027	2028
Gross Revenue	2,764,580	2,888,986	3,018,990	3,154,845	3,296,813
Revenue from energy sales	2,764,580	2,888,986	3,018,990	3,154,845	3,296,813
Sales Taxes	239,136	249,897.26	261,143	272,894.06	285,174
ISS	138,229	144,449	150,950	157,742	164,841
PIS/COFINS	100,907	105,448	110,193	115,152	120,334
Net Revenue	2,525,443	2,639,088	2,757,847	2,881,951	3,011,638
Operational costs	251,883	262,025	272,656	283,804	295,494
Operation and maintenance costs	207,343	216,674	226,424	236,613	247,261
Rate of Use of the Transmission System	35,260.48	35,260.48	35,260.48	35,260.48	35,260.48
Inspection Fee for Electric Energy Services	9,279.44	10,090.18	10,971.75	11,930.34	12,972.68
Gross Operating profit	2,273,560	2,377,064	2,485,191	2,598,146	2,716,144
Gross margin (%)	90.03%	90.07%	90.11%	90.15%	90.19%
SG&A	138,228.98	144,449.29	150,949.50	157,742.23	164,840.63
General and Administrative Expenses	96,760.29	101,114.50	105,664.65	110,419.56	115,388.44
Insurance	41,468.69	43,334.79	45,284.85	47,322.67	49,452.19
EBITDA	2,135,331	2,232,615	2,334,241	2,440,404	2,551,304
% EBITDA	84.6%	84.6%	84.6%	84.7%	84.7%
Depreciation	122,100.00	122,100.00	122,100.00	122,100.00	122,100.00
Financial expenses	261,800.00	196,350.00	130,900.00	65,450.00	0.00
Interest	261,800.00	196,350.00	130,900.00	65,450.00	0.00
LAIR	1,751,431	1,914,165	2,081,241	2,252,854.16	2,429,203.59
IR + CSLL	212,319.72	221,874.10	231,858.44	242,292.07	253,195.21
Net profit	1,539,111.4	1,692,290.5	1,849,383.0	2,010,562.1	2,176,008.4
% Net profit	60.94%	64.12%	67.06%	69.76%	72.25%

Table 4.15: Development of the Statement of Income for the Year (Year 6 to Year 10)

In the statement of income for the year presented, we can already see a growing profit margin for this operation. It is large because the operational costs and the SG&A of this type of business are relatively small compared to revenue. There are cases where the Mini Hydropower plant can work in an automatic or semiautomatic regime (as is the case), which makes operating costs low. It also does not require a large administrative body to support the operation. In addition, the profit margin is increasing due to the decrease of interest over the years. It is expected that after year 10, when the amortization of the loan is completed, and the debit balance is zero, the theoretical net income remains constant.

4.8 Cash Flow and Discounted Cash Flow

As described in Chapter 3, cash flow controls the financial inflows and outflows of a company and facilitates the observation of a favorable or unfavorable economic result for a given observed period. In this way, the cash flow will be used as a way to predict a possible loss or profit from the venture in the future.

Cash flow is comprised of "net income" (in fact, the net result, when it is positive) from the statement of income for the year, by the capital of the loan made to the BNDES that entered the "zero" year to make the necessary investments and for the depreciation that had been discounted in the statement of income for the year and will return to the company as cash.

The cash outflow is composed of the entire amount of the investment made in the year "zero" for the implementation of the Mini Hydropower plant and amortization of the loan over 8 years. If the statement of income for the year resulted in a net loss, this value may come from the cash outflow, but in the case studied, it was preferred to include the "loss" with negative value in the group of cash flow entries.

Thus, the cash flow of the venture is found by subtracting the total of entries with the total of exits each year. The values found can be observed in Tables 4.16 and 4.17.

In order to evaluate economic viability, it is still necessary to elaborate the discounted cash flow, which, when discounting inflation (time value of money) and attractiveness ratio of capital providers, will evaluate the economic wealth of a company.

First, we must calculate the net worth of the company over the years. In the year "zero", when the Mini Hydropower plant is not yet in operation and all the necessary investments are made to reactivate it, shareholders' equity is composed only of the necessary capital contribution. The total amount of equity to be injected into the company corresponds to the "loss" observed in the statement of income for the year. In turn, this loss corresponds to the remainder of the amount of initial investment required, since BNDES does not cover the entire amount, and interest on the financing of that same year. It is worth remembering that the National Bank for Economic and Social Development does not charge amortization for the first two years (two years grace period), but charges interest on the loan.

As of year one, with the venture already in operation, it is observed that the business still does not generate a result that covers the zero year loss. Only from year 7 the business starts to generate cash for the company (positive result). In this way, from that moment on, the shareholders' equity will be composed of the sum of the net worth of the previous year and the company's profit as shown in the cash flow.

After calculating the shareholders' equity, which represents the value that the shareholders have in the company at a given moment, we will consider the amount that the other injector of capital has in the company. For this, the amount of the remaining debt of the financing in each period was calculated.

Knowing now the amount that each actor has over the years studied, we will calculate the Weighted Average Cost of Capital. According to Damodaran (1997), WACC is the weighted average costs of the various financing components, including debt, equity and hybrid security, used by a company to finance its financial needs. In our study, it will be calculated according to the weighted average between the cost of equity (usually considered as the opportunity cost) times net worth, and the cost of capital of the financing company (which is the interest it takes) times the remaining value of the debt.

With the WACC calculated, other quick accounts are realized as the cumulative WACC and accumulated inflation to finally find the sum value between the WACC and the accumulated inflation. This result is multiplied by the final value of the cash flow from the first part of Table 4.16 to finally find the amounts observed in the last row of the Table 4.16. These values represent the discounted cash flow.

Cash Flow						
Period	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Year	2018	2019	2020	2021	2022	2023
1. Cash Inflow	6,315,925.00	812,228.58	1,084,414.36	1,223,530.49	1,365,937.03	1,511,779.90
Net income	229,075.00	690,128.58	962,314.36	1,101,430.49	1,243,837.03	1,389,679.90
Loan BNDES	6,545,000.00	0.00	0.00	0.00	0.00	0.00
Depreciation	0.00	122,100.00	122,100.00	122,100.00	122,100.00	122,100.00
2. Cash outflow	10,395,000.00	0.00	818,125.00	818,125.00	818,125.00	818,125.00
Investment	10,395,000.00	0.00	0.00	0.00	0.00	0.00
Amortization	0.00	0.00	818,125.00	818,125.00	818,125.00	818,125.00
Cash Flow	-4,079,075.00	812,228.58	266,289.36	405,405.49	547,812.03	693,654.90
Cumulative Cash Flow	-4,079,075.00	-3,266,846.42	-3,000,557.06	-2,595,151.57	-2,047,339.54	-1,353,684.64
Discounted Cash Flow						
Net worth	4,079,075.00	4,891,303.58	5,157,592.94	5,562,998.43	6,110,810.46	6,804,465.36
Remaining debt	6,545,000.00	6,545,000.00	5,726,875.00	4,908,750.00	4,090,625.00	3272500.00
WACC	9.29%	9.44%	9.59%	9.79%	10.01%	10.27%
WACC cumulative	9.29%	18.73%	28.32%	38.11%	48.12%	58.39%
Inflation cumulative	0.00%	4.50%	9.00%	13.50%	18.00%	22.50%
WACC + Inflation Cumulative	9.29%	23.23%	37.32%	51.61%	66.12%	80.89%
Discounted Cash Flow	-4,079,075.00	742,181.99	221,711.16	306,371.56	373,974.09	425,454.25
Cumulative Discounted Cash Flow	-4079075.00	-3336893.01	-3115181.85	-2808810.29	-2434836.20	-2009381.95

Table 4.16: Cash Flow and Discounted Cash Flow (Year 0 to 5)

Cash Flow					
Period	Year 6	Year 7	Year 8	Year 9	Year 10
Year	2024	2025	2026	2027	2028
1. Cash Inflow	1,661,211.40	1,814,390.47	1,971,483.00	2,132,662.09	2,298,108.39
Net income	1,539,111.40	1,692,290.47	1,849,383.00	2,010,562.09	2,176,008.39
Loan BNDES	0.00	0.00	0.00	0.00	0.00
Depreciation	122,100.00	122,100.00	122,100.00	122,100.00	122,100.00
2. Cash outflow	818,125.00	818,125.00	818,125.00	818,125.00	0.00
Investment	0.00	0.00	0.00	0.00	0.00
Amortization	818,125.00	818,125.00	818,125.00	818,125.00	0.00
Cash Flow	843,086.40	996,265.47	1,153,358.00	1,314,537.09	2,298,108.39
Cumulative Cash Flow	-510,598.24	485,667.22	1,639,025.22	2,953,562.32	5,251,670.70
Discounted Cash Flow					
Net worth	7,647,551.76	8,643,817.22	9,797,175.22	11,111,712.32	13,409,820.70
Remaining debt	2454375.00	1636250.00	818125.00	0.00	0.00
WACC	10.55%	10.83%	11.10%	11.36%	11.36%
WACC cumulative	68.94%	79.76%	90.87%	102.23%	113.59%
Inflation cumulative	27.00%	31.50%	36.00%	40.50%	45.00%
WACC + Inflation Cumulative	95.94%	111.26%	126.87%	142.73%	158.59%
Discounted Cash Flow	461,991.06	485,131.34	496,776.80	499,044.93	783,430.16
Cumulative Discounted Cash Flow	-1547390.89	-1062259.54	-565482.75	-66437.82	716992.34

Table 4.17: Cash Flow and Discounted Cash Flow (Year 6 to 10)

The analysis of the data in the cash flow Table once again proposes that the business is economically viable, since in the tenth year all the accumulated loss of previous years was slaughtered and converted into accumulated profit. This was only possible thanks to the lack offered by BNDES for the payment of amortizations. Otherwise, the second year of operation of the Mini Hydropower plant (year 2) would still be marked by the accumulated loss and the partners would have to inject more money into the company. Another important detail comes after the year 10 onwards: the debt with the financing bank ends and the cash register increases considerably. At the same time, the WACC only counts the cost of equity since there is no more external capital in the company to be amortized.

However, we will only be sure of the economic viability of this venture when we calculate and analyze the economic indicators of the business.

4.9 Investment analysis

4.9.1 Economic indicators

The main indicators to be considered in an economic feasibility study are: Net Present Value (NPV), IRR, Payback and Discounted Payback. All of them will be seen below (Table 4.18) and the conclusions will be taken.

Economic Indicators	
NPV	716,992.34
IRR	14%
Simple payback	6.51
Discounted payback	9.08

Table 4.18: Economic indicators

4.9.2 Net Present Value (NPV)

As discussed in Chapter 3 of this paper, the Net Present Value (NPV) is the method used to consider the value of money over time. That is, it is desired to bring all expected profits or losses of the company to present value, so that they can be compared and studied.

The NPV calculation is very trivial when you have discounted cash flow: just add up all the values in the "net cash flow" line. Thus, calculating the next 10 years, the NPV is R$ 716,992.34.

As NPV has given a positive value, we can conclude that the venture creates value for the shareholder over 10 years.

4.9.3 Internal rate of return (IRR)

The internal rate of return (IRR) is the rate of return that indicates the point at which the Net Present Value cancels out, the rate from which it is not worth the investment.

Thus, its calculated value for the present study is 14.04%. This rate is considered quite high for an investment opportunity.

4.9.4 Payback and Payback Discounted

Payback is the time elapsed so far at which the net profit of the business equals the initial investment made. That is, from that particular moment, the enterprise starts to generate profit for the shareholder. Discounted Payback has the same principle, but uses in its calculation the values obtained in the discounted cash flow, since it counts on the variance of the money value in time.

Therefore, the value found for Payback is 6.51 years. Discounted Payback is bit bigger, worth 9.08 years. Such values are quite attractive in the finance industry for an opportunity.

Chapter 5

Discussion of Findings

5.1 Introduction

Makaron (2012) presented in his paper the feasibility analysis of the construction of the Small Hydropower plant Fartura, which will take advantage of the hydroelectric potential of the river Engano and will be built in the course of this river in the municipality of Angelina, in the State of Santa Catarina, southern Brazil. The Small Hydropower plant Fartura project consists of a diversion plant that operates by water, with a powerhouse consisting of two generation units with total installed power of 5MW. The author concluded that this undertaking was not viable in the current context. The main limitation was the price of energy sales. The sale price of energy that provides a return on investment and meets the financing conditions of the BNDES, stands at R$ 166 / MWh. However, in the last regulated auction, the ceiling price was set at R$ 101 / MWh.

Furthermore, on the same case, the author approaches the competitiveness of the SHPs in relation to the price range of sale of energy that makes feasible the enterprise. Compared to other alternative sources of energy and large power plants, Small Hydropower plants in Brazil have low competitiveness. Some factors contributed to the loss of competitiveness: a) the increase in construction costs, which represent 35% of the total investment; b) the lack of isonomy in relation to the other alternative sources, firstly due to the fact that wind farms are exempt from taxes, which represents a reduction of 15% of the total cost. A second point of differentiation is the process of enabling other alternative sources of energy in regulated auctions. SHPs are the only ones subject to the requirement of prior environmental licensing.

In a study carried out by Mancebo (2013), the object of the case study is a Mini Hydropower plant located on the edge of the city of Lima Duarte, Minas Gerais. The case study shows a drop of 8.5 meters and a flow of 7.3 m^3 / s and the installed capacity will be 515 KW, using a turbine of the Bulb type. After analyzing the economic indexes, the author concluded that the venture is feasible, since it presents a low need for injection of equity capital, payback of just over a year, IRR of 55.21%

and a NPV of more than 700 thousand in 10 years. However, the author considers that more precise technical studies are necessary so that errors do not significantly impact the final result.

Candido (2012) elaborated a work with the objective of analyzing a Mini Hydropower plant as an investment, through a real case study, in the Northern region of Brazil, highlighting the implementation and maintenance costs for a period of 20 years, to verify economic viability. The project will be built in the eastern region of the state of Pará, on the Ribojinho river, a tributary of the Itacaiúnas river. An existing drop will be used allowing the installation of 0.8 MW / h of generating power.

After an economic analysis of the study, the author verified that the company reaches a high profitability as soon as the amortization period of the financing that occurs in the eighth-year ends, by calculating the discounted payback, which surpasses the expectation of return. Therefore, it is concluded that the project is feasible provided that it is prepared with solid and accurate information on various aspects related to the project, such as unit price, forecast of inflation indexes among others and considering the assumptions used.

5.2 Suggestions for further research

The main limitation of the present work is inherent to the methodology of case studies. Indeed, case studies make generalizations unreliable. In order to minimize this limitation in the performed analyzes, a reflection was sought not only of the focused study, but also of comparisons with the practices of the market of Mini Hydropower plants.

As suggestions for future work, it is recommended not only the application of the methodology in a greater number of real cases, but also studies that lead to the proposition of a methodology for calculating the cost of capital in private companies, taking into account the specificities of the sector. Considering that the cost of equity and third parties are parameters that have a direct influence on the result of the operation, small variations in these parameters can lead to results that are far from the reality that is unique in each case of smaller generation projects.

5.3 Summary and conclusions

This work had as main objective the analysis of the critical success points of the feasibility study of small electric power generation projects using Screw Turbines. Additionally, it was tried to evaluate how the main variables of this type of enterprise impact the economic-financial result of the project. For this, we started with a theoretical approach regarding the context and characterization of the Mini Hydropower plants until the validation of the reflection of the proposal through a Case Study.

The purpose of the discussion was divided into five chapters. The first one detailed the central issue and the main and secondary objectives, that is, detailed the pillars of the approach that guided the rest of the work. It was observed that the relevance of the theme is due to the important role that the Mini Hydropower plants play in the composition of electricity supply in Brazil.

In the second chapter, which contextualized the demand and supply of energy in Brazil, it was observed that the country shows a tendency to increase consumption per capita. From the point of view of generation, the national demand continues to be supplied predominantly by hydroelectric sources, more specifically 65% of the electric energy consumed.

In the third chapter, the methodology for the elaboration of the economic model of project evaluation was presented. Investors, when evaluating a project, seek to obtain sufficient cash generation to compensate the opportunity cost for investment risk. In addition, the electric sector has a peculiarity that distinguishes it from other sectors. Such peculiarities make it of fundamental importance for the entrepreneur to map out the risks to which he is exposed when he decides to build a Mini Hydropower plant. The last part of Chapter 3 described the cash flow components of a project and the procedures for obtaining the key variables.

Chapter 4, in turn, presented the feasibility study of the project, which proved feasible and safe harbor for the investor.

The first part of chapter 5 sought to confront the results found in this case study, with works of other authors in order to compare the data obtained. The great majority of the works concluded that the implantation of smaller plants is viable.

The study of the energy sector and how the small hydropower plants are inserted in the sector helped in the understanding of the importance of this type of enterprise for the development of the Brazilian energy matrix. Recent studies show that Mini Hydropower plants tend to grow in importance in the generation of energy in Brazil, mainly due to the aforementioned economic and environmental advantages of such type of generation project and to governmental incentives, as previously mentioned.

Through asset valuation methods: Discounted Cash Flow, Internal Rate of Return, Simple Payback and Discounted Payback the present work sought to identify the economic feasibility of a Mini Hydropower plant project, in light of different variables that affect the returns of the investor.

The studies elaborated by several authors showed that the investment has good prospects of economic-financial return and can be an attractive investment if better known by the entrepreneurs. It is important to emphasize that the project demands a longer maturation time due to the high initial investment, this factor should be considered when taking into account the expected return time of the investors in the project.

For the scenario constructed using justified premises, such as cost of capital, investment need, energy price, capital structure, costs and charges, considering the energy price in the captive market obtained in the last auction of R$ 141.82 / MWh, the analyzed enterprise obtained an internal rate of return of 14.04%, extremely attractive compared to the weighted average cost of capital of 8.1%. This fact demonstrates the economic viability of this type of project in Brazil, even with the greater need of investment per MW of power in this type of project compared to the construction of a large hydroelectric plant.

It can be concluded that projects of Mini Hydropower plants, which are alternative sources of energy, besides being less aggressive to the environment, are also great value generators for entrepreneurs.

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ANEEL	National Electric Energy Agency
APESC	Association of Energy Producers of Santa Catarina
BIG	Generation Information Bank
BNDES	National Bank for Social and Economic Development
CGU	Single Generating Plant
COFINS	Contribution to the Financing of Social Security
CSLL	Social Contribution on Net Income
DCF	Discounted Cash Flow
EBITDA	Earnings Before Interest, Tax, Depreciation and Amortization
EPE	Energy Research Company
FGV	Getulio Vargas Foundation
IRR	Internal Rate of Return
IRPJ	Income Tax for Legal Entity
ISS	Tax Over Services
LHP	Large Hydropower Plants
MHP	Mini Hydropower Plants
MME	Ministry of Mines and Energy
NPV	Net Present Value
PP	Photovoltaic Power Plants
PIS	Social Integration Program
PROINFA	Alternative Energy Sources Incentive Program
SHP	Small Hydropower plants
TNP	Thermonuclear Plants
TP	Thermal Plants
TUSD	Distribution System Use Tariff

TUST	Rate of Use of the Transmission System
TSFEE	Rate of Inspection of Electric Energy Services
WACC	Weighted Average Cost of Capital
WIN	Wind Generation