

Economic Feasibility Study for The Installation of a Cogeneration System in A Timber Industry of Lages-Sc

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Abstract

This research thematic is the Economic Viability Study, in order to implement a cogeneration system, in a logging company, located in the Santa Catarina highland plateau region. Thus, reducing its production cost, since much of it is due electricity purchase. Data collection of both production, consumption and expenses with electricity purchase and billing were carried out together with the company. Descriptive method was used, with case study. For the economic analysis, both net present value (NPV), internal rate of return (IRR) and payback period were used. With this information and crossing the data, the economic viability for this project became evident, as it can be visualized throughout of this article.

Keywords: Electrical energy; cogeneration; investment; biomass.

1. Introduction

With the economic instability that is devastating the Brazil in recent years and with the dynamics of the world stage, companies seek differentials, which become more competitive and thus can lower production

costs to survive in a globalized market.

Brazil has 163,848,441 kW of installed power 63.76% come from hydroelectric plants, however, despite the Brazilian energy matrix come from largely a generation of lower cost, the final price of the electric energy is still high, which raises the cost of production (ANEEL, 2019).

According to the DIEESE in 2014 (Department of Statistics and Socio-economic Studies) the rate of electricity presented opposite trend observed in 2013, positively and gradually from the second half of the year. The year ended with an increase of approximately 17.0%. As we all know, 2014 was marked by the deepening of unfavorable hydrological conditions, which dried up not only shells of the plants, but also some important reservoirs for water supply, as the largest city in the country. The low level of the reservoirs of power plants has caused the generation of hydroelectric energy stayed well below installed capacity, which required the full and continuous drive of power plants, more expensive sources of generation (DIEESE, 2015).

Due to skyrocketing energy prices, which has taken place since the year 2015, the industry seeks alternatives such as more efficient consumption and cogeneration. Being this second alternative the case study of this project. "Energy has a strategic position in society, and may be regarded as an essential input to the implementation of practically all human activities and economic development." (LORA, 2004).

For this case study will be used by the company, information such as power consumption, of waste in the production line (biomass), steam consumption in wood drying kiln and your billing.

The high cost of production today facing timber makes these companies seek a better economic efficiency. In this context, improving energy efficiency is considerable, and reduce the amount spent on purchase of electric energy is the determining factor for lower production costs, making them more competitive.

According to the LPF/Ibama (forest products laboratory), the approximately 50 million cubic metres of timber logs extracted per year in the Amazon region produce only 20 million cubic meters of sawn timber. Of the total, approximately 60% is wasted in sawmills during primary processing. In General, over 20% are wasted on secondary processing, generating a huge amount of waste (SANTA CATARINA, 2015).

2. Methodology

This research paper requires the use of descriptive methods, because it is a case study, making an analysis of the electric energy self-production, using the system of cogeneration and also your economic viability. We used qualitative methods using documentary data provided by the company to perform the work and a bibliographical research.

To check whether it is economically viable for the company, the investment in cogeneration, it will be necessary to study the indicators associated with the return and the associated risk indicators, such as net present value (NPV), internal rate of return (IRR) and Investment recovery period (PAYBACK).

3. Bibliographic Review

3.1 Cogeneration

cogeneration is the combined utilization of steam to generate electricity for motive power and heating, i.e.

the steam generated in the boiler passes through a turbine which is coupled to a generator, then steam the resulting proceeds to industrial process given the other uses and driving heat, for example, in wood drying kilns (PATUSCO, 1993). Figure 1 shows the representation of a cogeneration system.

According to the Clemente (2003), cogeneration is synonymous with cost reduction, with reduction of energy dependence. For companies that are able to co-generate in their facilities, this can be the most economical way to meet the internal needs of steam and electricity, reduce operating costs and increase the reliability of supply.

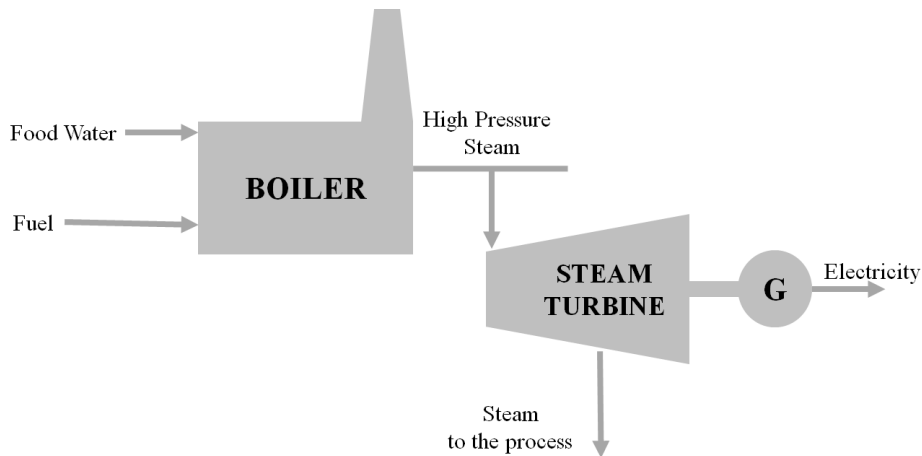


Figure 1. Cogeneration system.

3.2 Steam boiler

Steam boilers (Figure 2) are equipment to produce steam under pressure above a space, using any source of energy, except for the reference and decorative materials used in process units (BRASIL, 1978).

The boiler is a water fed by a pump with pressure higher than the work of the boiler, which is directed to a bank of tubes and is one of the gases that most contribute to the burning of the biomass. After that, the water goes to the steam pipe, it is not tubing that is separated from the water vapor.

At the bottom of the pipe, the pipes, in turn, are separated by water and furnace from the boiler, returning as vapor to the top of the pipe. Steam to the superheater and proceed to the process.



Figure 2. Steam Boiler of Biomass (ENGE CASS, 2017).

3.3 Steam Turbine

The steam turbine is a device that harnesses the power of steam to calorifica turns it into mechanical energy of rotation. Figure 3 shows an illustration of the main elements consisting of a steam turbine.

The high pressure steam enters the nozzles, which are the passages formed by the stationary blades, these direct the steam shovels to shovels. The steam flow changes direction as it passes on the canals between the stationary blades, this change of direction generates a force under the paddles that will move the turbine shaft (YANAGIHARA, 2016).

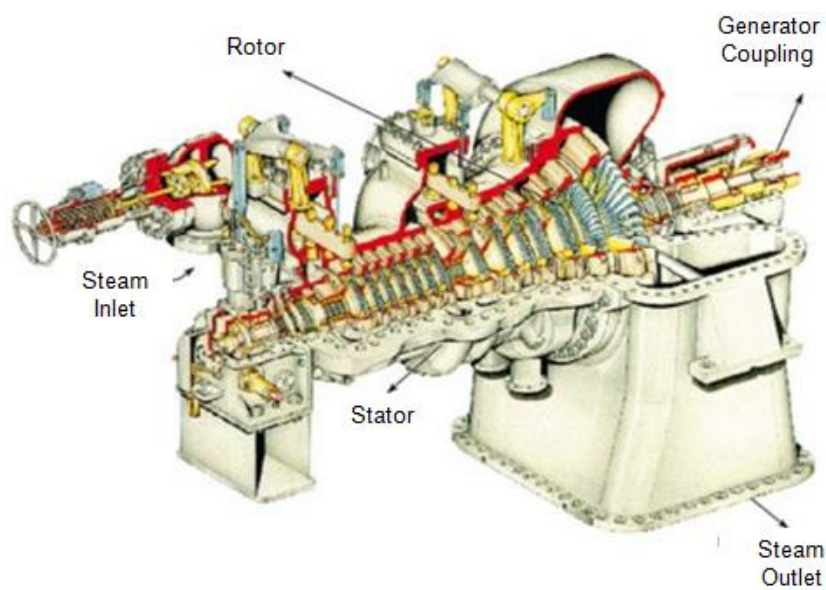


Figure 3. Component parts of a steam turbine (RENOVE TECNOLOGÍA, 2009).

For use in this case, the turbine indicated is back (escape with higher pressure than atmospheric), where the steam enters the admission 22 Kgf/cm², temperature 385°C and in the exhaust comes out with 8 Kgf/cm² and 291°C (Engecass, 2017).

3.4 Generator

The generator is a machine that converts mechanical energy of rotation into electrical energy. The mechanical energy can be supplied by the steam turbine, by wind, by a drop of water among others.

A simple generator consists of a strong magnetic field and constant; drivers who rotate through the magnetic field; and some way to keep an electrical contact keep drivers as they rotate.

The magnetic field is produced by the current that traverses the stationary field coil (stator). The excitement for the field coil is supplied by a battery or any DC source. The rotor, also called the rotor turns within the magnetic field. For a single coil of wire around the rotor, each end is connected to separate collector rings, isolated from the axis. Each time the rotor turns completing a rotation occurs a complete cycle of alternating current.

In practice a generator contains hundreds of coiled coils in rotor slots. Two brushes are pressed through Springs against the rings collectors, so as to maintain a continuous electric contact between the alternating current induced in the rotor and the external circuits (GUSSOW, 2009).

3.5 Biomass

The energy point of view, to order granting industry enterprises electric, biomass is every renewable resource originating from organic matter (of animal or vegetable origin) that can be used in the production of energy. As well as hydropower and other renewable energy sources, biomass is an indirect form of solar energy. Solar energy is converted into chemical energy through photosynthesis, base of the biological processes of all living beings (ANEEL, 2005).

In Figure 4 shows the schematic diagram of energy conversion of biomass. Direct combustion is the transformation of the chemical energy of the fuel into heat, through the reactions of the components with the oxygen provided. For energy purposes, the direct combustion occurs primarily in stoves (food cooking), ovens (metallurgy, for example) and boilers (steam generation, for example) (ANEEL, 2005). In the company, arrive in your patio fence of 8,000 tons/month of logs to be benefited, however, only 50% of this total will turn the finished product on the production line. Therefore, 4,000 tons/month is generated in this process residue, i.e. biomass.

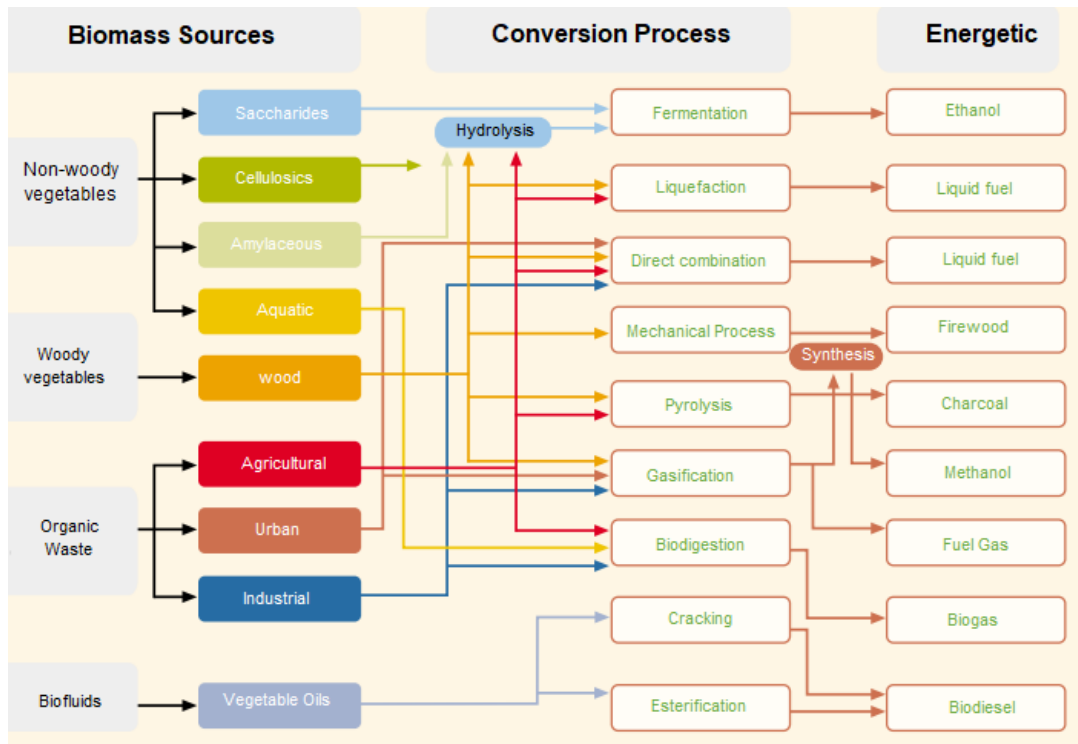


Figure 4. Diagram of the processes of energy conversion of biomass (adapted from ANEEL, 2005).

3.6 Net Present Value (NPV)

Net present value is a technique of analysis of investment cash cash flows of the company at a specified rate, using as a discount rate the TMA company. The NPV is the concentration of all the expected values of a cash flow in zero date. The NPV is obtained subtracting from the initial investment of the project of the present value of cash entries, discounting the opportunity cost rates used in the project itself. Both the entries as the outflows are translated into monetary values current (SOUZA & CLEMENTE, 2001).

According to Sanvicente (1996, p. 118) if the NPV is greater than zero, that means the company will get a return greater than your cost of capital, so you accept the project if NPV is less than zero, reject the project because, in this case, the return is less than the cost of capital used by the company in project.

3.7 Internal Rate Of Return (IRR)

Is defined as the discount rate that equates the present value of cash entries to the initial investment and a project, that is, is the discount rate that makes the NPV of an investment opportunity match-if the zero. The criterion of the TIR decision making has the following reasoning: when the IRR is greater than the TMA, so is adding value, therefore, accepted the project, if the IRR is smaller than the TMA, rejects the project (SOUZA & CLEMENTE, 2001).

3.8 Investment Recovery Period (Payback)

The Payback period refers to the number of periods needed for the flow of benefits exceed the invested capital and is usually expressed in number of years (HOJI, 2000). For Sousa (2007), the payback represents an important flag, associated with the time factor, the investor would be deposited to assume.

There are two approaches: the simple Payback, who works with cash entries for the dates that are expected

to occur without the application of any discount rate. And the discounted Payback, where the future cash entries, to end if amortization of initial investment, are presented in present values (SOUSA, 2007).

3.9 Pressure Reducing Valve

According to Ramos, Covas e Araújo (2004), the pressure reducing valves reduce a high pressure to an adjustable value after the valve. A spring holds the open valve that closes with increased pressure.

In the project under study this pressure reduction occurs on steam turbine, but if necessary the installation in parallel the turbine, a pressure reducing valve, thus stopping any plant when the need for maintenance in turbogenerators.

3.10 The Company

A logging company studied is an exporter and importer of lumber products, began its activities in the field of sawn wood in October 2007 in the mountainous region of the State of Santa Catarina, Brazil. Benefit products such as fences, handrails, stakes and lumber of various sizes. Currently, about 80% of the production of the company is committed to export, especially to the United States. With annual sales of around R\$ 20,195,448.93 for the year 2016, generating a total of 108 direct jobs and 50 indirect.

4. Search Results

In the specific case of this case study reach logging an average of 8,000 tons of log/month, however, only 50% reach the end of the process as a finished product, the other 50% generate waste as sawdust and chips. In 18 months the consumption of electricity purchased from the dealership generated a total cost of R\$ 1,804,274.12 (array + Branch), an average of R\$ 102,703.65 per month.

The best project after this study is the cogeneration using a back-pressure turbine, so the steam generated in the boiler of biomass will pass by the turbine, which will be coupled to a three-phase generator, providing electricity to the company and the surplus This generation will be directed to the concessionaire. After passing by the steam turbine is used for drying of wood in the kiln and after the steam heat exchange becomes condensed and back to the process, data presented in Figure 5.

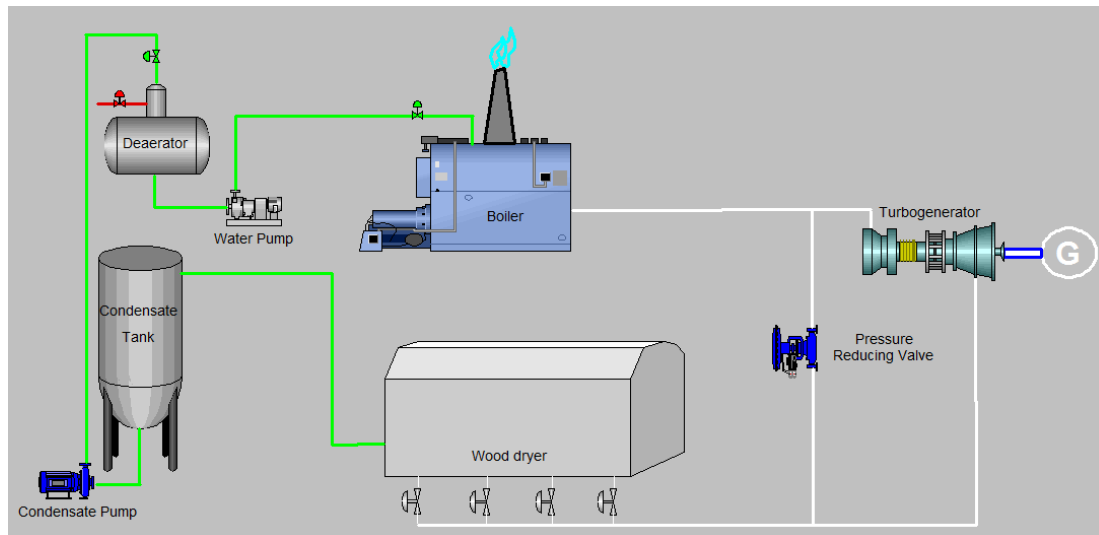


Figure 5. Schema of the cogeneration plant (Author, 2018).

4.1 Data Survey

The data in table 1 presents the data of cogeneration equipment. In the table 2 are listed the cost of the investment to be realized. The value required for the execution of the project are R \$3,300,000.00.

Table 1: Data of the equipment

	Pressure (Kgf/cm ²)	Temperature (°C)	Consumption (ton/h)		Generation	
			Biomass	Steam	kW/h	ton/h
Turbo generator	20	385		6	1000	
Pressure Reducing Valve	22/8	385				
Saturation valve	8	385/170				
Deaerator	1.2	120				
Boiler	22	385	2.4			6

Source: Engecass (2018).

Table 2: Investment

Investment of Equipment (R\$)	
Turbo generator	1,710,000.00
Pressure Reducing Valve	18,000.00
Saturantion valve	12,000.00
Transport	75,000.00
Assembly	225,000.00
Boiler	1,260,000.00
Total	3,300,000.00

Source: Engecass (2018).

In table 3 and 4 are presented 18 months of electric energy consumption and 12 months of matrix electric power consumption of the branch. One can see that the average consumption is concentrated in the array 152,691 kW/month, the branch consumes an average of 7,887 kW/month, but in terms of values, the results are significant. In the array the lower consumption happened in January 2011, with 86,495 kW and higher consumption occurred in August 2017 with 169,812 kW

Table 3: Electric energy consumption data

Analysis of electric power Consumption (Array)				
Month	Consumption(kW)	Accrued (kW)	Invoice (R\$)	Accrued (R\$)
October/16	144,273	144,273	80,699.11	80,699.11
November/16	144,867	289,140	83,210.31	163,909.42
December/16	149,188	438,328	84,591.85	248,501.27
January/17	86,495	524,823	51,201.63	299,702.90
February/17	138,609	663,432	77,116.97	376,819.87
March/17	146,842	810,274	84,100.79	460,920.66
April/17	170,442	980,716	99,670.75	560,591.41
May/17	155,581	1,136,297	87,647.72	648,239.13
June/17	158,351	1,294,648	93,703.70	741,942.83
July/17	158,462	1,453,110	88,185.70	830,128.53
Agust/17	169,812	1,622,922	99,778.31	929,906.84
September/17	162,136	1,785,058	104,842.00	1,034,748.84
October/17	168,605	1,953,713	113,208.22	1,147,957.52
November/17	167,934	2,121,647	114,053.95	1,262,011.47
December/17	165,015	2,286,662	112,879.39	1,374,890.86
January/18	137,795	2,424,457	92,861.05	1,467,751.91
February/18	164,880	2,589,337	141,715.51	1,609,467.42
March/18	159,103	2,748,440	139,317.28	1,748,784.70
Average	152,691		97,154.71	

Source: data provided by the company.

Table 4: Electric energy consumption data of the branch

Analysis of electric power Consumption (Array)				
Month	Consumption(kW)	Accumulated (kW)	Consumption(R\$)	Accumulated (R\$)
October/16	0	0	0	0
November/16	0	0	0	0
December/16	0	0	0	0
January/17	0	0	0	0

February/17	0	0	0	0
March/17	0	0	0	0
April/17	0	0	0	0
May/17	0	0	0	0
June/17	5,559	5,559	3,867.69	3,867.69
July/17	9,102	14,701	5,516.27	9,383.96
Agust/17	8,226	22,927	5,379.83	14,763.79
September/17	8,238	31,165	5,944.00	20,707.79
October/17	6,616	37,781	5,142.97	25,850.76
November/17	8,448	46,229	6,352.12	32,202.88
December/17	6,563	52,792	5,048.28	37,251.16
January/18	9,374	62,166	6,452.01	43,703.17
February/18	8,461	70,627	6,124.33	49,827.50
March/18	8,232	78,859	5,661.92	55,489.42
Average	7,886		5,548.94	

Source: data provided by the company.

In table 5 and 6 presents an analysis of the investment in the company. With the investment of us R\$3,300,000.00, would have an annual savings of R\$1,343,353.46. That without considering the effects of inflation and the depreciation of equipment. If we consider inflation, the results would be even more significant. The project is viable, because we have an NPV of R\$ 867,681.15 and an internal rate of return of 22.81%, as the rate of attractiveness was 10%, our IRR, is well above the market rate. If we take into account the size of the company, the same could capital at BNDES, with much lower interest rates. Our simple Payback, happens in 2 years, five months and 14 days and the discounted Payback in 3 years. For this type of project, the result is excellent, because it would be acceptable even with twice as much time.

Table 5. Analysis of return on investment

Month	Investment and Return				
	Year 0	Year 1	Year 2	Year 3	Year 4
Final cash flow	-3,300,000.00	1,343,353.46	1,343.353.46	1,343.353.46	1,343,353.46
Cumulative cash flow	-3,300,000.00	-1,956,646.54	-612,888.33	730,465.13	2,073,818.59
Discounted cash flow	-3,300,000.00	1,210,228.34	1,090,295.80	982,248.47	884,908.53
Discounted cash flow accumulated	-3,300,000.00	-2,089,771.66	-999,478.86	-17,230.39	867,678.11
NPV		867,681.15			

IRR 22.81%

Table 6: Simple payback and discounted Payback-balance point

Month	Investment recovery period (Payback)		
	Year	Month	Day
Simple Payback	2	5	14
Discounted Payback	3	0	0

5. Conclusion

In the analysis of this work a mountainous region requires thermal and electrical energy for the manufacture of the final product, so the cogeneration process is justified in the economy generated front the purchase of electric energy of the concessionaire, whereas, the steam is already used, which is inherent in the process. The general goal was to perform the analysis of the economic viability has been completely achieved, the project was viable, in addition to the shows company reduce costs with the purchase of electric energy, the capital invested in the project demonstrates a considerable return, the discounted payback happens after the third year of operation of the turbo-generator. The NPV was R\$867,681.15 and IRR was 22.81%.

Many difficulties had to be overcome for the implementation of this article, since personal problems, which came to interfere directly in gathering data in the enterprise where the study was conducted, as was also very difficult to get the budgets for the equipment needed for the project. Unfortunately the Brazilian companies, perhaps by little culture of investments in research with universities, or even by just targeting profit, passed budgets (the who gave a return) superficial, without a lot of technical data, in which kept contact, were not few, to total ten companies of the area.

In environmental terms, this project brings a considerable return, since all the water in the boiler, used today is discarded in the form of condensate after the thermal Exchange in wood drying kiln, with the cogeneration system, it forms a closed loop, where the condensate returns to the process, is to steam saturation, and/or to feed the boiler, i.e. all the water used will be reused. Another plus point is with regard to residues of the process, only 50% of the logs that come off the logging will turn the final product, so with 43.2% project execution of this biomass residue will be used in the boiler.

Of this research is as a recommendation for future work, the use of the rest of the biomass waste to an even larger generation of electricity, which would add value to this material, which is currently sold for a value negligible for companies in the mountainous region.

6. References

ANEEL. Biomassa. In: ANEEL. **Atlas de Energia Elétrica do Brasil**. 2. ed. Brasília: Aneel, 2005. Cap. 5. p. 77-92.

ANEEL. **BIG:** Banco de Informações de Geração. 2019. Disponível em: <<http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm>>. Acesso em: 28 mar. 2019.

BRASIL. Norma Regulamentadora nº NR-13, de 08 de junho de 1978. Nr 13 - Caldeiras e Vasos de Pressão (113.000-5). Brasília, DF.

CLEMENTE, Leonardo. **AValiação DOS RESULTADOS FINANCEIROS E RISCOS ASSOCIADOS DE UMA TÍPICA USINA DE CO-GERAÇÃO SUCRO-ALCOOLEIRA.** 2003. 93 f. Monografia (Especialização) - Curso de Pós Graduação em Planejamento, Operação e Comercialização na Indústria de Energia Elétrica, Universidade Federal do Paraná, Curitiba, 2003.

DIEESE – **Comportamento das Tarifas de Energia Elétrica no Brasil,** 2015. [internet]. Disponível em: <<https://www.dieese.org.br/notatecnica/2015/notaTec147eletricidade.pdf>>. Acesso em 01/11/2017.

ENGECASS (Rio do Sul). **Produtos:** Caldeiras. 2017. Disponível em: <<http://www.engecasscaldeiras.com.br/produtos/caldeiras>>. Acesso em: 15 out. 2017.

GUSSOW, Milton. **Eletricidade Básica.** 2 ed. Porto Alegre: Bookman, 2009.

HOJI, Masazaku. **Administração Financeira:** uma abordagem Prática. São Paulo: Atlas, 2000.

LORA, Electo Eduardo Silva; NASCIMENTO, Marco Antônio Rosa do. **Geração Termelétrica:** planejamento, projeto e operação. Rio de Janeiro: Interciência, 2004.

PATUSCO, J. A. M. Tratamento da Cogeração nos Balanços Energéticos. COBEN 08/93. 1993.

RAMOS, Helena; COVAS, Dídia; ARAÚJO, Luiz. VÁLVULAS REDUTORAS DE PRESSÃO E PRODUÇÃO DE ENERGIA. In: CONGRESSO DA ÁGUA, 7., 2004, Lisboa. **Anais...** . Lisboa: Aprh, 2004. n. 114. Disponível em: <<http://www.aprh.pt/congressoagua2004/PDF/114.PDF>>. Acesso em: 28 mar. 2019.

RENOVE TECNOLOGÍA (Madrid). **Principales Elementos.** 2009. Disponível em: <<http://www.turbinasdevapor.com/index.php/principales-elementos>>. Acesso em: 28 mar. 2019.

SANTA CATARINA. Governo Estadual. Diretoria de Sistema Econômico. **Biomassa.** 2015. Disponível em: <<http://www.scmaisenergia.sc.gov.br/sds/?p=136>>. Acesso em: 20 out. 2017.

SANVICENTE, Antônio Zorato. **Administração financeira.** São Paulo: Atlas, 1996.

SOUSA, Almir Ferreira de. **Avaliação de Investimentos**. São Paulo: Saraiva, 2007.

SOUZA, Alceu; CLEMENTE, Ademir. **Decisões financeiras e análise de investimentos**. São Paulo: Atlas, 2001.

YANAGIHARA, Jurandir Itizo. **Máquinas Térmicas**. São Paulo: Poli Usp, 2016. Color.

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