GESTÃO, FINANÇAS E CONTABILIDADE

APPLICATION OF REAL OPTIONS THEORY IN THE EVALUATION OF SWINE BIOGAS STORAGE

APLICAÇÃO DA TEORIA DE OPÇÕES REAIS NA AVALIAÇÃO DE ESTOCAGEM DO BIOGÁS SUÍNO

APLICACIÓN DE LA TEORÍA DE OPCIONES REALES EN EL EVALUACIÓN DEL ALMACENAMIENTO DE BIOGÁS A PARTIR DE EXCREMENTO DE CERDOS

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ABSTRACT
This paper evaluates the real option of storing the biogas from swine biomass. We analyze deferring the immediate sale of this energy in the spot market to store it in the form of gas for future sale. We consider that once a storage tank reaches maximum capacity, the producer will sell all of the energy generated in either the spot market or regulated market for a minimum selling price. The farm we chose to study already produces energy and sells it in the spot market. The real options methodology was chosen to consider managerial flexibility and the uncertainty of the energy price. Additionally, considerations were made for the stochastic process applied to the price time series of the weekly Differences Settlement Price (Preço de Liquidação das Diferenças in Portuguese) of low voltage power in southern Brazil. Our results indicate that the storage option has value for the power generation from swine biomass.
Keywords: electric power, renewables sources, swine biomass, real options theory.

RESUMO
Este artigo avalia a opção real de armazenar o biogás a partir da biomassa suína. Analisamos o adiamento da venda imediata dessa energia no mercado *spot* para armazená-la sob a forma de gás para venda futura. Consideramos que uma vez que um tanque de armazenamento atinge a sua capacidade máxima, o produtor venderá toda a energia gerada no mercado à vista ou no mercado regulamentado, por um preço mínimo de venda. A fazenda em estudo já produz energia e vende no mercado à vista. A metodologia de opções reais foi escolhido para

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considerar a flexibilidade gerencial e a incerteza do preço da energia. Além disso, as considerações foram feitas para o processo estocástico aplicado à série histórica de preços semanais do Preço de Liquidação das Diferenças de potência de baixa tensão no sul do Brasil. Os resultados indicam que a opção de armazenamento tem valor para a produção de energia a partir de biomassa suína.
Palavras-chave: energia elétrica, fontes renováveis, biomassa suína, teoria de opções reais.

RESUMEN

En este trabajo se evalúa la opción real de almacenar el biogás a partir de biomasa porcina. Analizamos el aplazamiento de la venta inmediata de esta energía en el mercado *spot* para almacenarla en forma de gas para la futura venta. Consideramos que una vez que un tanque de almacenamiento alcanza su máxima capacidad, el productor venderá la totalidad de la energía generada, ya sea en el mercado *spot* o en el mercado regulado, por un precio mínimo de venta. La finca objeto de estudio ya produce energía y la vende en el mercado *spot*. La metodología de opciones reales fue elegida pues considera la flexibilidad administrativa y la incertidumbre del precio de la energía. Además, se hicieron consideraciones para el proceso estocástico aplicado a la serie de precios semanales del Precio de Liquidación de las Diferencias (Preço de Liquidação das Diferenças en portugués) de energía de baja tensión en el sur de Brasil. Nuestros resultados indican que la opción de almacenamiento tiene un valor para la generación de energía a partir de biomasa porcina.
Palabras clave: energía eléctrica, energías renovables, biomasa porcina, teoria de opciones reales.

1. INTRODUCTION

After the 2001 electricity rationing in Brazil, the government began encouraging the development of alternative energy sources through the establishment of the Incentive Program for Alternative Sources of Electric Energy (PROINFA in Portuguese) in 2004. The program's goal was to diversify the energy matrix by increasing projects of alternative energy generation, such as wind, biomass, and small hydroelectric plants.

Among the sources encouraged by PROINFA, biomass had great expectations for growth (EPE, 2010). Biomass includes any renewable resource from organic matter, such as plants, animals, and urban or agricultural waste. Sugar cane is the most commonly used biomass in Brazil to produce ethanol. Additionally, biogas has prospered due to its being perennial and environmentally friendly.

Biogas is a renewable energy source that is a mixture of 65% methane (CH4) and 35% carbon dioxide (CO2) (GUSMÃO, 2008). According to Angonese *et al.* (2006), biogas is an alternative to reduce oil dependency. Biomass is attractive to large-scale production due to its wide availability and its potential for power generation and reduction of waste pollution.

In this context, this paper analyzes the managerial flexibility of biogas energy storage for a power generation project that used biomass derived from swine biogas. The modeling of managerial flexibility linked to the uncertainty in energy prices can positively impact business value, which is not captured by traditional testing methods, such as Discounted Cash Flow (DCF).

It is necessary, therefore, to apply appropriate tools, such as real options theory, since flexibility generally adds value to a project and its correct modeling can impact investment decisions, see for example Costa *et al* (2014). It is important to note that this theory is the most appropriate to measure managerial flexibility in projects, since it considers the manager's ability to adapt to new information during the course of the project, resulting in a more precise and realistic analysis (BASTIAN-PINTO, 2009).

The literature on the application of the real options approach in the evaluation of power assets has mainly addressed thermal plants due to the managerial flexibility associated with such investments (CAPORAL and BRANDÃO, 2008). The actual options that exist for these projects were studied by Griffes, Hsu, and Kahn (1999), who identified a variety of options in addition to operational flexibility, such as growth, abandonment, waiting, conversion, and repowering.

Caporal and Brandão (2008) proposed a model to evaluate a unit of power generation under uncertain conditions, including the flexibility of choosing the sale mechanism of the energy by the real options approach, and applied this to a small hydroelectric plant. Oliveira (2012) examined the feasibility of cogeneration with forest residues and natural gas as fuel, and concluded that the option of selling the excess energy added value to the project.

There is no reference to the application of the real options approach to swine biomass, as the studies on the generation of biogas from swine waste are still rather recent (e.g., OLIVEIRA and HIGARASHI, 2006; CERVI, ESPERANCINI and BUENO, 2010; MARTINS and OLIVEIRA, 2011) and do not consider the option of storage of the surplus energy for later sale in the spot market.

The price of energy in the spot market is a key variable in the evaluation of power generation projects. However, the volatility of the spot price is significantly high in Brazil, which implies an environment of significant uncertainty for producers (LEITE and SANTANA, 2006). Our aim is to verify the economic viability of the storage of the biogas generated from swine biomass. Therefore, we analyzed the option of postponing the immediate sale of the energy in the spot market to storing that energy in the form of gas for later sale.

First, we analyzed the Brazilian Energy System and its need for investment in alternative sources. Second, we determined the environmental impacts of swine waste and how it can be used as animal biomass in the production of biogas. Third, we evaluated how energy can be sold in the Brazilian market. Finally, we applied the real options evaluation methodology to determine the financial viability of the project and its possible gains.

Our results indicate that the option to store biogas for future sale in the spot market has value for the producer. Also, this study contributes a way to reduce environmental pollution and treat swine waste. Finally, we conclude that carbon credits can be sold after producing biogas from swine waste due to the reduction in the emission of methane gas. Further, the investment in producing biogas from swine waste meets the PROINFA goals of diversifying the Brazilian energy matrix and searching for renewable sources.

This paper is organized as follows. The second section describes the theoretical framework of the main thematic. The third section addresses the modeling of the stochastic process. The fourth section presents the results and analysis. Finally, the fifth section presents the conclusions and proposals for future research.

2. THEORETICAL REFERENCES

2.1. The Brazilian Electricity Market

The Water Code established in 1934 aimed to regulate the Brazilian Electricity Sector, without any previous regulation and supervision by the state. However, the code established so many rules and restrictions on companies that a sense of uncertainty about the future of the electricity sector developed and, consequently, the sector lost its attractiveness for investment (GOMES *et al.*, 2002).

Given the reduction in outside investment, the government continuously invested in the sector, generating a great period of growth based on the availability of low interest international credit and the tax instruments used to finance the sector (CAPORAL and

BRANDÃO, 2008). This changed in the early 1980s due to the end of foreign credit and rising inflation, leading the public sector into a severe fiscal crisis that lasted throughout the following decade, as well as a strong reduction in power generation investments (ENNES, 1995).

In order to change this situation, the Brazilian Energy Sector underwent a major restructuring coordinated by the Ministry of Mines and Energy in the 1990s. This reform intended to attract private investment and improve the financial performance of the sector through its segmentation into generation, transmission, distribution, and commercialization.

The reform also led to free competition in the sectors of production and commercialization, and the creation of the Wholesale Energy Market, now called the Electric Energy Trading Chamber (Câmara de Comercialização de Energia Elétrica in Portuguese), to account for and settle trade transactions between energy producers. Following the energy crisis of 2011, the restructuring of the Brazilian Energy Sector was intensified in 2004, with the creation of two energy trading markets: the Free Market (Ambiente de Contração Livre (ACL) in Portuguese) and the Regulated Contracting Environment (Ambiente de Contratação Regulada (ACR) in Portuguese).

The agents who buy and sell energy in the Free Market freely negotiate their contracts, while the Regulated Contracting Environment hiring is regulated by the government. This new model aimed to ensure the safety of the electricity supply through clear and uniform rules and procedures, and to ensure the inclusion of new agents and free competition.

According to Oliveira (2012), the restructuring focused on energy procurement planning through long-term contracts to generate predictable cash flow and favored obtaining credit lines to support the project in the early years, mainly during the construction phase. However, Guedes and Fonseca (2007) discussed the model's paradoxical character, because at the same time the government sought to increase the number of both domestic and foreign investors and participants in the industry, it wanted to maintain its control over the transmission system.

In addition, Rosa (2007) criticized the dependence on rainfall for power generation, because the Brazilian energy matrix was predominantly hydropower. Rosa stated that if not for the heavy rains in 2007, Brazil would have experienced increased energy costs due to the need to use the thermoelectric system. This is in accordance with the findings of Melo (1999) that extended periods of drought tend to raise the price of electricity, while periods of above average rainfall tend to fill the reservoirs and reduce the price of electricity.

Therefore, the price of energy in Brazil is subject to strong fluctuations since the generation of hydroelectric power, the main source of energy, is linked to the level of water in reservoirs. As described on the National Electric Power System Operator website (2014 - Operador Nacional do Sistema de Energia Elétrico in Portuguese), due to the drought, the reservoirs were below 45% of total capacity, with the exception of those in the North, in the beginning of 2014. Due to this, and to avoid power rationing, the government began solely utilizing the thermoelectric system, which led to an increase in the cost of energy in the spot market and eventually in the Regulated Contracting Environment.

Despite hydroelectric power generation being less expensive than other sources, it is unreliable and presents a risk to Brazilian development since its price is strongly linked to reservoir water levels. Changes in energy prices have far-reaching impacts, from the intensive electricity sector to households, which will have less disposable income and will also suffer from the higher costs of production and services. This emphasizes the need to intensify the restructuring that began in 2000, with the aim of diversifying the Brazilian energy matrix.

2.2. Energy Commercialization in Brazil

Brazil began restructuring the electricity sector in 2003, due to the new federal government determining that previous problems, specifically electricity rationing, were motivated by the market model adopted in the 1990s (LOSEKANN, 2008).

In this context, the Ministry of Mines and Energy (MME) formulated and implemented a new model for the Brazilian Electric Sector and the institutional and legal bases were approved by Congress in 2004 by the Laws 10.847 and 10.848. These laws divided the Brazilian electricity market in two trading environments with clearly distinct and logical structuring, one a regulated market and the other a free market.

In a Regulated Contracting Environment, electricity is sold between producers and distributors, and the contracting is formalized through Power Purchase Agreements. Regulation begins when energy distributors inform the National Electric Energy Agency (ANEEL in Portuguese) and MME of its demand forecast for current consumers in the coming years. Based on the current consumption, these forecasts, and the current capacity of the country's generation, government entities develop a series of studies and organize energy auctions to meet future demand (CCEE, 2011).

On the other hand, in the Free Market, producers and consumers negotiate the amount of energy to be sold, the price of the contracts, and the terms of the agreement. These features are discussed directly between the parties concerned. If the agreement is formalized, the producer registers the contract in the Electric Energy Trading Chamber (CCEE in Portuguese) platform, subject to user approval.

In general, the Free Market is composed of the following agents: free and special consumers, traders, producers, distributors, and self-producers. A self-producer, the agent of interest in this study, is characterized by producing energy for their own consumption and eventual sale with prior authorization (ABREU and AZEVEDO, 2009).

Table 1 shows the energy consumption of the participants in the Free Market from March 2013 to February 2014. It is important to note that the free and special consumers accounted for the majority of consumption, on average 72.4%. On the other hand, the self-production and independent production together corresponded to 21.9%. In addition, according to the report of the CCEE in 2014, consumption in the Free Market was restricted to the industrial sector, and other sectors of the economy accounted for 12.45%. This is low participation in the Free Market by other sectors of the economy when compared to the industrial sector. This contrasts with the investment opportunities, for example, as suggested in this study, where a swine producer can venture into the electricity self-production market by selling biomass.

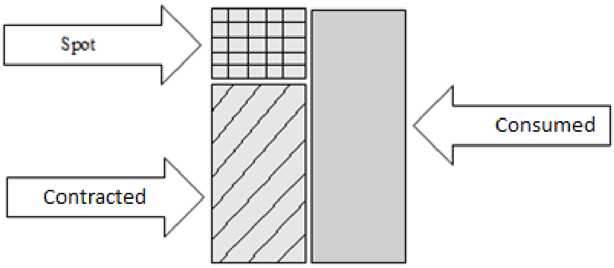
Table 1 - Energy consumption in The Free Market in GWh

Class	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sept 13	Oct 13	Nov 13	Dec 14	Jan 14	Feb 14
FC	7.14	7.03	7.21	6.95	7.24	7.29	7.06	7.36	7.08	6.90	7.20	6.60
SC	1.41	1.40	1.40	1.34	1.39	1.42	1.38	1.48	1.42	1.32	1.43	1.37
SP IP	2.68	2.66	2.66	2.54	2.66	2.75	2.55	2.59	2.56	2.45	2.47	2.26
Generator	710	684	684	673	715	666	656	709	666	705	744	640
Total	11.9	11.7	11.6	11.5	12.0	12.1	11.6	12.1	11.7	11.3	11.8	10.8

Nota: FC - Free Consumer, SC - Special Consumer, SP - Self-producer, IP - Independent-producer.
Source: CCEE – InfoMercado, n. 80, april/2014

The accounting and settlement of electricity transactions produced and consumed in Brazil are conducted by the Electric Energy Trading Chamber. These functions use the record of the purchase and sale of electricity, monitor the contracted amounts, and record what was effectively used and produced. The differences calculated between the contracted and consumed electricity are accounted for in the spot market, as shown in Figure 1.

Figure 1 - Accounting energy available in the system



Source: adapted from Caporal and Brandão (2008)

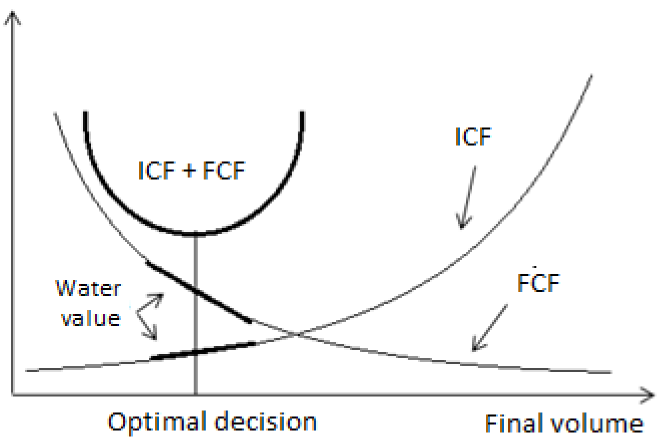
Debits and credits earned in the spot market are valued at the spot price, or the Differences Settlement Price (DSP) (Preço de Liquidação das Diferenças in Portuguese). This price is calculated on a monthly basis using mathematical models that define the Marginal Cost of Operation (MCO), or the cost of producing an additional energy unit to be consumed by the market.

According to Caporal and Brandão (2008), once the MCO is calculated, the Administrator of the Wholesale Energy Market Services publishes the spot market price, which is equal to the MCO of each Brazilian region (North, Northeast, South, Southeast). This is the price used to settle transactions between complementary market players for their bilateral contracts.

The MCO is a junction between an Immediate Cost Function (ICF) and a Future Cost Function (FCF). The ICF increases if the volume of reservoirs increases and causes the thermoelectric system to be more expensive. The FCF decreases if the volume of the reservoirs increases and the thermoelectric plants will not be used (GOMES and LUIZ, 2009).

In this scenario, the optimal use of stored water corresponds to the point that minimizes the sum of the immediate and future costs. As shown in Figure 2, the minimum total cost point corresponds to the point at which the derivative of the ICF and FCF to water storage is equal.

Figure 2 - Great use of water



Source: adapted from Gomes and Luiz (2009)

2.3. Alternative Energy Sources

The current energy supply has become increasingly vulnerable, given the dependence on non-renewable resources, such as coal and oil, where depletion of these natural resources would impact the current social system. Thus, alternative sources may contribute to establishing a sustainable energy model.

Thus, the Federal Government, through Law No. 10438 of 2002, established the Incentive Program for Alternative Sources of Electric Energy, to increase the share of electricity generated from biomass, wind, and small hydropower plants in the National Interconnected System (NIS).

Among the alternative sources encouraged by the government, the National Energy Balance from 2010 (EPE, 2010) showed an increasing share of biomass in the Brazilian energy matrix, from 23.3 TWh (terawatt hours) to 27.4 TWh. This increase was mainly from cogeneration systems, which use the steam generated in boilers burning the bagasse from sugar cane, for example, to turn steam turbines that generate electrical and thermal energy (SANCHES, 2003).

Biomass creates biofuels, such as ethanol and biodiesel, and bio-energy, such as organic waste, which can be obtained from new biomass (manure, food waste, and other waste) and old biomass (wood and straw). New biomass is mainly used to generate electricity from biogas, which is then accumulated in a gasometer, while old biomass is used in thermal power generation by burning these materials.

The use of swine biomass for power generation has been widely discussed (see MARTINS AND OLIVEIRA, 2011). Pig farming poses major environmental problems due to the large concentration of animals in small spaces and the inadequate management of swine waste, which reduces water quality, produces unpleasant odors, and hinders the development of fish and other water organisms.

For these reasons, the use of biomass derived from swine waste contributes to the protection of the environment, and can provide the energy needed for electricity, heat, and fuel.

In general, each pig group produces up to 25 m^3 of waste per year, which includes manure, urine, drinking and cleaning water waste, and feed residues (KONZEN, 1980).

The total waste produced varies according to the body development of the animals, with decreasing values from 8.5 to 4.9% when considering a body weight range from 15 to 100 kg (JELINEK, 1977).

According to Oliveira (1993), each liter of water ingested by a pig can result in 0.6 L of liquid waste. The volumes of waste produced by different categories of pigs are shown in Table 2, as well as their equivalence in m^3 of biogas.

Table 2 - Daily production of swine waste

Pigs Category	Manure kg/day	Manure + urine kg/day	Liquid waste L/day	Biogas (CH4)/day m^3
25-100 kg	2.3	4.9	7	0.17
Nuts in pregnancy	3.6	11	16	0.27
Nut in lactating	6.4	18	27	0.48
Males	3.0	6	9	0.23
Piglets weaned	0.35	0.95	1.4	0.03
Mean	2.35	5.80	8.60	0.18

Source: adapted from Oliveira (1993).

Table 3 shows the correlation of energy production of biogas in relation to other sources of energy according to three authors.

Table 3 - Energy equivalence of 1 m^3 of biogas

Energy	FM	S	N
Gasoline (L)	0.61	0.61	0.61
Kerosene (L)	0.58	0.58	0.62
Diesel (L)	0.55	0.55	0.55
LPG (L)	0.45	0.45	1.43
Alcohol (L)	-	0.79	0.80
Coal (Kg)	-	0.74	0.74
Firewood (Kg)	-	1.54	3.50
Electricity (Kwh)	1.43	1.43	-

Note: FM – Ferras e Mariel; S – Sganzerla; N – Nogueira.
Source: Ferraz e Mariel (1980), Sganzerla (1983) e Nogueira (1986)

Therefore, the proper management of swine waste is a health, ecological, and economic need. Swine waste impacts health because the waste can harm animals and humans, both inside and outside the property. It has ecological impacts because the waste, rich in organic matter and nutrients, pollutes and destabilizes the environment. Finally, it has two main economic impacts: (i) the treatment of waste involves equipment resources, material, and labor, which affect the production system and can even paralyze it; (ii) the production of biogas from swine waste can result in energy self-sufficiency, which is a way to reduce the final cost of production and generate additional sources of income through the sale of energy surplus, carbon credits, and biofertilizers.

2.4. Self-production and Surplus Commercialization

In the Free Market, as discussed earlier, there are two types of energy producers: self-producers and independent-producers. While the former produces for its own consumption, and could sell the surplus production in the spot market, the latter produces for the sole purpose of commercializing the energy generated.

Fundamentally, these agents have two forms of energy production from alternative sources: large blocks of energy and small generator modules. The large blocks of energy, as in the case of wind and solar sites, could replace current plants as these sites have operating characteristics similar to conventional generation (SEIXAS, PASCHOARELLI JR and FARIA JR, 2005)

However, the small generator modules could be used for local needs to complement the larger system (SEIXAS, PASCHOARELLI JR and FARIA JR, 2005). The small modules are typically used in rural or remote areas due to the difficulty of integrating them with the main system and their high cost.

In 1999, the ANEEL regulated the direct sale to consumers, procedures for connection to the main system, and use of the core network, transmission systems, and distribution. This regulation imposed charges to facilitate the connection of the electrical system to entrepreneurs interested in trading energy, as well as the construction of the transmission line and the purchase of necessary equipment.

These rules generated some access barriers when connecting to the distribution system. First, a network equipment connection required such knowledge of the technical and regulatory standards that often discouraged the generating projects from selling their surplus production. Second, the cost of acquiring equipment for the connection was the exclusive responsibility of the project generating the energy (PALOMINO, 2009).

Finally, Zanatto Jr. and Teixeira (2011) listed the major difficulties encountered by cogeneration when connecting to the distribution system:

- Request by the distributors for sophisticated designs;
- High resource requirements for the connection;
- Obligation to donate assets to the distributors.

3. METHODOLOGY

Storing biogas for future sale in the spot market has operational flexibility that can increase the revenue of rural investors who have a structure of power generation and a network connection. However, this flexibility causes the traditional DCF method to underestimate the real value of the enterprise.

Thereby, an appropriate tool to quantify the managerial flexibility is the Theory of Real Options (TRO), which assesses management's ability to adapt to new information more accurately. Dixit and Pindyck (1994) described three basic conditions required for a project to be evaluated by the TRO: uncertainty of its future value, an investment that is at least partially irreversible, and managerial flexibility.

The stochastic variable can be modeled by a Geometric Brownian Motion (GBM). The general equation is defined by Equation 1.

$$dP_t = \alpha P_{t-1}dt + \sigma P_{t-1}dz \qquad (1)$$

Where

- dP_t is the change in the incremental price in the time interval dt,
- α is the growth rate of the price in the range dt, also called drift,
- σ is the volatility of the energy price, and
- $dz = \varepsilon\sqrt{dt}$, where is $\varepsilon \sim N(0,1)$ is the standard Wiener process.

Hull (1999) considered the risk neutral evaluation as an important tool in the analysis of derivatives, and used the risk-free rate as the discount factor. To model the risk neutral process the risk premium (π) was included in Equation 1 to develop Equation 2, as used throughout this study.

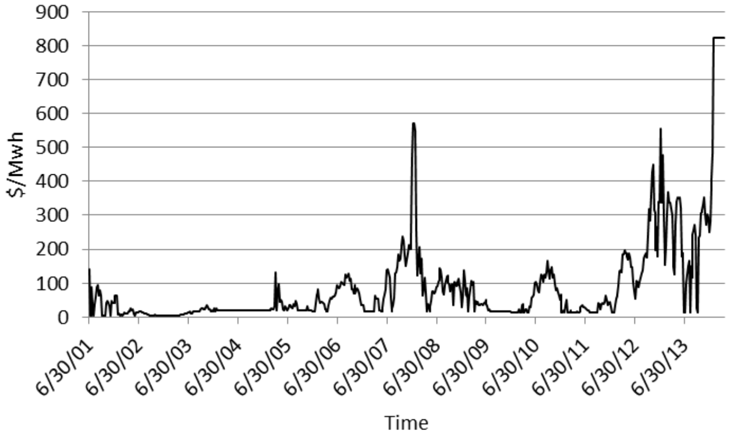
$$dP_t = (\alpha - \pi)P_{t-1}dt + \sigma P_{t-1}dz \qquad (2)$$

The parameterization of the drift, process trend, and energy price volatility followed the work of Bastian-Pinto (2009). Thus, the volatility parameter was obtained from the standard deviation of the series and the drift parameter was the average of the same series, which was added to half of the variance.

3.1. Validity of the Stochastic Process

The uncertainty in the project under study was the spot price of energy, given by the Differences Settlement Price (DSP), which has a future value that is at least partially random. The data considered were the weekly DSP prices of the light load of the Brazilian South region in the period from the first week of July 2001 to the fourth week of April 2014, which included a total of 673 observations obtained through the CCEE website. A graph of the price data is shown in Figure 3.

Figure 3 – Weekly DSP prices in $/MWh from 01/Jul to 14/Apr



The DSP is used to value the energy sold in the short-term market and uses the data considered by the National Operator of the System (NOS), an agency that manages Brazil's power grid, to optimize the operation of the NIS. Due to the preponderance of hydroelectric plants in the Brazilian generation park, mathematical models are used to calculate the DSP, which aims to find the optimal solution between the present benefit of water use and the future benefit of its storage, which is measured according to the economy expected from the thermal power plant fuels.

The DSP is determined weekly for each load level based on the marginal cost of operation. It is limited by a maximum and minimum price for each period of assessment for each submarket. The time intervals of each level are determined for each month by the NOS and provided to the CCEE for consideration through the Accounting and Settlement System (ASS).

To model the DSP and calculate the price of the real option, it was necessary to understand what stochastic process was more appropriate for the price series in question. Therefore, it was necessary to verify the existence of a unit root in the series of prices. The existence of a unit root indicates an integrated process of order one, or a non-stationary series, which is best modeled by a GBM. If the existence of a unit root was not verified, indicating that the series is stationary, the Middle Reversal Movement (MRM) is more appropriate to represent the behavior of the price series.

The mean reversion movement is associated with a long-term equilibrium price, which attracts the price to a level over time through a mechanism of supply and demand (BASTIAN-PINTO, 2009). However, the MRM can be too predictable, and the GBM is more appropriate for modeling future uncertainties, as studied by Bastian-Pinto (2009).

To ratify the modeling of the stochastic variable, we performed stationary tests on the available data. Thus, as in Brooks (2008), to test for the stationarity of the data, we used confirmatory analysis of a unitary root Dickey-Fuller (DF) test and a Kwiatkowski-Phillips-Schmidt-Schin (KPSS) stationary test on the logarithms of the series of prices. The results are listed in Table 4.

Both tests are considered methods developed for the unit root test that, according to Maddala and Kim (1998), have more power (the probability of not making a Type II error) and size. The hypothesis testing of the DF follows the traditional method in which the null hypothesis series follows a random walk (i.e., not stationary). However, for the KPSS test, the null hypothesis is stationary. Therefore, the KPSS test was performed to supplement the DF test, since one of the major criticisms of this test is its lack of accuracy in distinguishing coefficients close to one, such as 0.95 (Brooks, 2008).

Table 4 – Dickey-Fuller Unit Root Test and KPSS Stationary Test

Result DF			Result KPSS									
Order of lags:	8		Order of lags:	15								
Statistics:			Statistics:	Lag	Kpss	Lag	Kpss	Lag	Kpss	Lag	Kpss
	-1.9			0	25.4	4	5.71	8	3.35	12	2.42
				1	13.3	5	4.84	9	3.05	13	2.27
				2	9.14	6	4.21	10	2.8	14	2.14
				3	7	7	3.73	11	2.6	15	2.02
Critical Values:	1%	-3.4	Critical Values:								
	5%	-2.8		1%	2.5%	5%	10%				
	10%	-2.5		0.7	0.5	0.4	0.3				

The test results on the logarithm of prices do not support the hypothesis that the diffusion process does not follow a GBM. While the DF test does not reject the null hypothesis of a unit root, the result of the KPSS test does not reject the null hypothesis of the stationarity of the series. Thus, we opted for modeling through a MGB, which is consistent with the literature (see, for example, CAPORAL and BRANDÃO, 2008).

Thereby, to find the parameters of the series of prices, which are the drift (α) and the volatility (σ), we calculated the log-return series for each price where the volatility parameter is the standard deviation of the series and the average is the drift, which is added to half of the variance. Thus, the results of the weekly DSP indicated that the volatility was roughly 0.51 and the drift was 0.13. This was calculated with a risk premium (π) of 5% per year. The historical average energy price is $ 89.2 MWh (all values are in local currency). It was also considered that the stochastic process could not exceed the maximum amount of $ 822.83, a value set by the National Electric Energy Agency for 2014.

4. RESULT ANALYSIS

4.1. Data

The modeling and resultant data were used to evaluate the real option of biogas booking derived from swine biomass from a pig farm in the South of Brazil. The South of Brazil holds 49.5% of all the Brazilian swine herd (IBGE, 2012), and produces some energy from swine biogas. Therefore, it is of interest to evaluate this region.

The swine farm chosen for analysis had 7,000 animals, which produced on average 17.500Kg of manure per day, totaling 1.470m^3 of manure daily. This is a rough average based on the findings by Dias et al. (2013), Ferrarez, Filho, and Teixeira, (2010), and Martins and Oliveira (2011). The production system (swine) generates residue (biomass) that is converted into methane, which is then used as fuel by the producer. Biogas is the basic input for electricity production from a farm. This product is the result of the anaerobic digestion of pig manure and has a high potential for combustion due to the presence of methane.

According to Martins and Oliveira (2011), 1m^3 of biogas is equivalent to 1.43kWh, and 1 kg of manure generates 0.08m^3 of biogas daily. Thus, considering that a farm with an 18-hour operating capacity per day will produce 40.083m^3 of biogas per month, while the monthly consumption of the farm will be around 24.583m^3, this leaves a surplus of 15.500m^3, or 22,165kWh, per month. This surplus can be sold either immediately in the spot market or stored for future sale.

For this study, we considered that the farm already had the digester and generator engine with enough capacity to carry all of the energy generated and/or stored to the network. Thus, the expenses that the producer must incur to store gas were the purchase of a storage tank and the labor for installation, making a total investment of $423.060,00. This investment is the option exercise price of storing the surplus energy. The weekly cost of the tank maintenance was neglected during modeling.

It was assumed that the stochastic process occurs in the same range as the time series of the light load of weekly prices of the South, i.e., weekly Δt. Once we defined and structured the energy value of the diffusion model, the inclusion of managerial flexibility was performed by inserting the moment of decision Δt as the option to be chosen. The producer faced a replacement option, or switch option, to decide between selling the energy in the spot market and storing the gas to sell in the future.

Thus, at each time Δt, the manager chose to sell or store the resource, given the energy price at that time. The storage tank chosen for analysis had a maximum capacity of 14,300kWh. Thus, it was assumed that if the energy produced exceeded the tank limit, the producer would have to sell the stored energy more than the energy produced during the week. Thus, the producer was faced with a new option: selling the energy in the spot market or the regulated market with the fixed price of $300,00MWh, which has a drift of 5%. It was assumed that this price was guaranteed in the regulated market for a maximum stock, so it is a desirable price.

Finally, similar to current data, the risk-free rate used to discount revenue was the DI rate, currently around 10.8% per year.

4.2. Discussion of Results

One of the most traditional techniques to value investment projects is the Net Present Value (NPV) technique, which is based on the DCF. The NPV method determines the present value of future earnings discounted at an appropriate interest rate less the cost of the investment. This method, however, may lead to incorrect decisions. According to Dixit and Pindyck (1994), this method ignores two important characteristics of investment decisions: the irreversibility of the investment and the managerial flexibility.

Therefore, this paper presents the results for both the NPV calculations and the real options method. The investment decision in the first case is conditional to a positive NPV (NPV>0). Thus, projects with a negative NPV (NPV<0) are rejected. This rule is not necessarily true for the real option method. According to the TRO, a manager could invest in strategic projects, meaning projects with options, even with a negative NPV (DIAS, 1996). In this way, the real options method allows a manager to maximize gains in favorable situations and minimize losses in adverse situations (BREALEY and MEYRS, 1992).

The real option concept was developed by Myers (1997) to provide investment opportunities that could be performed as a call option on real assets. Thus, real option investments are investments that give companies the right but not the obligation to take certain action in the future. In our study, the producer had the option of storing the energy and the option of selling the energy in the free market or regulated market.

To estimate the NPV, we calculated the present value of future revenues of the sale of energy in the market. The NPV with and without the option was defined as:

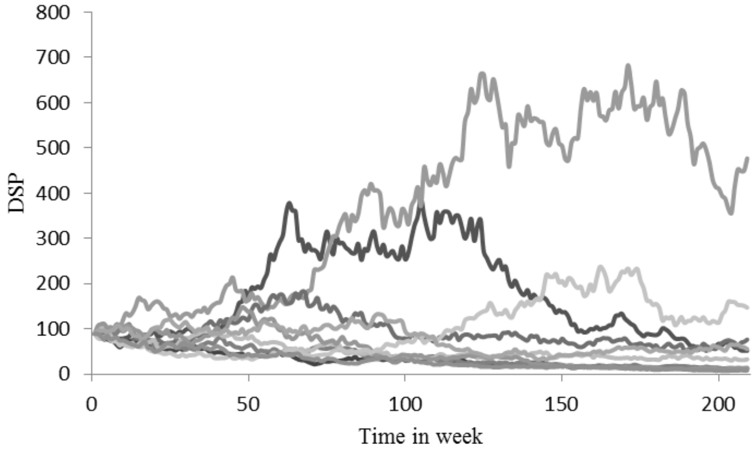
$$If \begin{cases} PLD^e > m & Rec = (Est^{t-1} + Est^t) \cdot PLD^e \\ PLD^e < m & \begin{cases} Rec = (Est^{t-1} + Est^t - Est^{max}) \cdot PLD^e, & if\ Est^{t-1} + Est^t > Est^{max} \\ 0, & \text{otherwise} \end{cases} \end{cases}$$

Where,

PLD^e: Stochastic series of DSP.
m: Minimum selling price.
Rec: Owner revenue.
Est^t: Gas stock in the period t.
Est^{max}: Maximum stock.

The NPV with the option is the present value of revenues with the option less the investment for the tank. The DSP values were estimated according to Equation 2. Figure 4 shows some of the simulation results.

Figure 4 – DSP Simulations



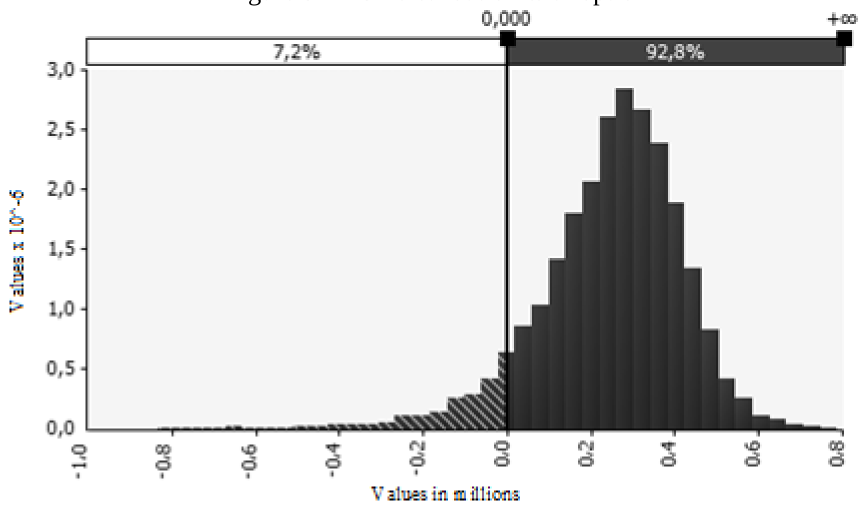
First, we considered the project without managerial flexibility and computed the present value of the project using the traditional NPV method with the financial parameters listed in Table 5. The value of the project without the option was $244.230,00.

Table 5 – Parameters for evaluation

Assumptions	Values
Sale price minimum	300 $
Energy produced	5.54 MWh
Maximum capacity of stock	14.3 MWh
Investment cost	423,060.00 $
Discount rate - WACC	15% a.a.
Risk Free Rate	10.8% a.a.
Life of the tank	4 Years

Then, we estimated the project value with the option. In this case, the result for the expanded NPV was $258.870,00. Figure 5 shows the NPV distribution with the option. The variables of risk premium and maximum stock followed a uniform distribution where U(0.03; 0.07) and U(14.30), respectively. The investment was modeled as a log-normal distribution with a mean of 423.060 and a standard deviation of 150.000. The variables of selling price and drift of sale were modeled as triangular distributions where T(250,300,250) and T(0.03, 0.05, 0.06), respectively. These results suggest that the option is significant up to $14.640,00.

Figure 5 - DCF distribution with option



Source: output @Risk.

The farm under study already had the capacity of generating biogas from swine biomass. It, however, had not considered the possible gains from carbon credit sale. A feasibility study of the sale these credits had been conducted previously. Generating biogas electricity could, however, obtain Certificates of Reduced Emissions or carbon credits (FERRAREZ, FILHO and TEIXEIRA, 2010), which could expand business gains.

Sensitivity analysis is a tool used to compare the results from simulations. Its practical approach addresses the problem of uncertainty. By varying one or more of the input data, uncertainties that may significantly affect the outcome and intensity of the simulation may be identified. With this technique, it is possible to identify the strengths and opportunities of a project.

Sensitivity analysis increases management's ability by providing security and perception of management decisions. Thus, we analyzed parameters that had a strong impact on the producers' decisions when deciding to invest in a gas storage tank. These variables were the selling price, risk premium, initial investment, and sale drift. The results of this analysis are shown in Figures 6, 7, 8, and 9.

Figure 6 – Sensitivity on the sale price

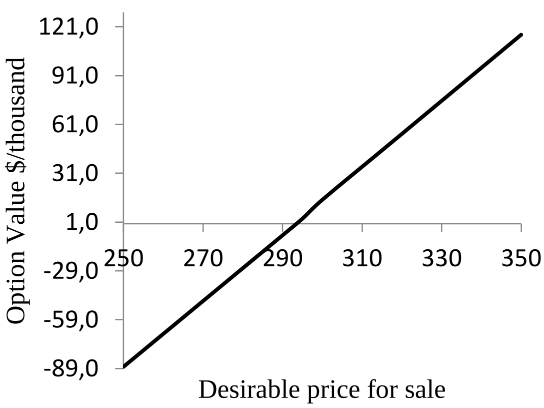


Figure 8 - Sensitivity on investment

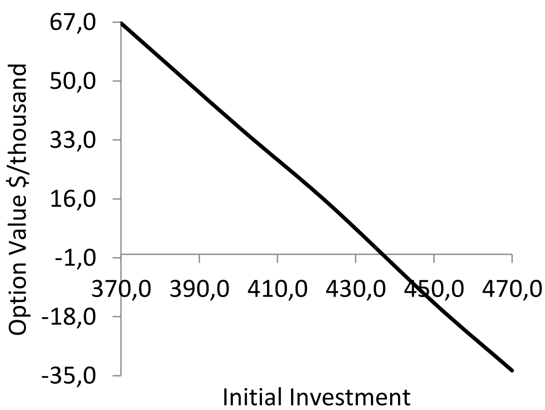


Figure 7 – Sensitivity on the risk premium

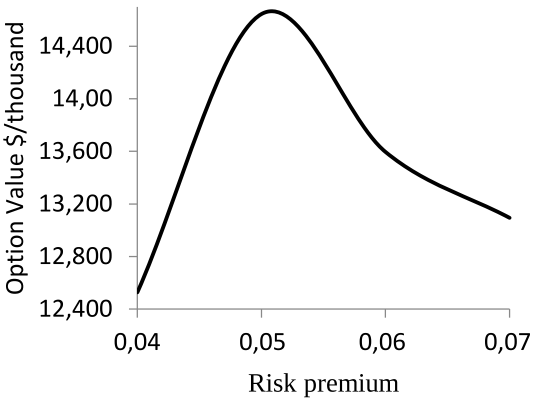
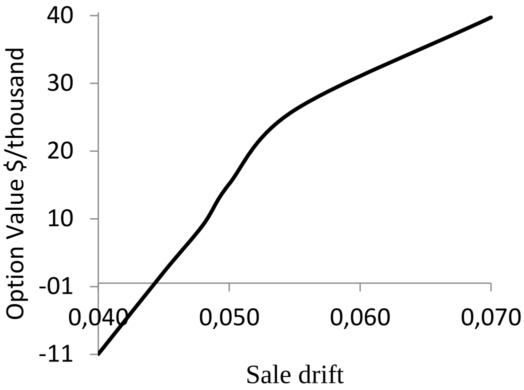


Figure 9 – Sensitivity on the sale of drift



As expected, an increase in the desirable selling price (the expected selling price in the regulated market) and sale drift increase the option value. When the tank reaches the maximum capacity, the producer has a minimum guaranteed sale price that would make the project viable.

An increase in the initial investment has a negative linear impact on the value of the option. This indicates that the farm is not able to support a very high investment for a biogas storage tank, which prevents the option. Finally, the risk premium analysis indicates that a good reward is around 5% per year, which confirms the initial calculations.

5. CONCLUSION

This study aimed to verify the financial and economic viability of storing the biogas generated from swine biomass. We analyzed, in addition to the traditional method of NPV, the option to defer the immediate sale of the energy in the spot market for the storage of the biogas for future sale.

The financial evaluation by the method of real options indicated that the storage of the surplus energy is viable. Additionally, the results showed that when the tank reaches maximum capacity and the energy spot market price is below the price minimum desired by the producer, the sale of the energy in the regulated market adds value to the project.

We obtained a value of approximately $14,000 for the option. This result reaffirms the importance of considering the uncertainty and managerial flexibility of the project as ways to aggregate value to the producer.

Importantly, as the manure produced by pigs is collected daily from the stalls, producing power from swine mass biogas helps reduce pollution. Without the proper treatment, manure is used as fertilizer and the soil is contaminated due to the highly polluting methane gas. Furthermore, a farm will stop emitting methane, which is a gas that contributes to global warming.

Similarly, another benefit is the possible sale of carbon credits. In this sense, future studies could study the commercialization of these carbon credits and their possible economic benefit to businesses with the real option.

REFERÊNCIAS

ABREU, Y. V. e AZEVEDO, M. R. M., **Racionamento de Energia Elétrica de 2001: o Estado do Tocantins**, Espanha: Eumed. net, Universidade de Málaga, 2009.

ANGONESE, A.; CAMPOS, A. T.; ZACARKIM, C. E; MATSUO, M. S e CUNHA, F.. Eficiência energética de sistema de produção de suínos com tratamento dos resíduos em biodigestor. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.10, n.3, p.745-750, 2006.

BASTIAN-PINTO, C. L. **Modelagem de opções reais com processos de reversão à média em tempo discreto: uma aplicação na indústria brasileira de etanol**, 2009. Tese (Doutorado em Administração de Empresa) – Programa de Pós-Graduação no IAG Escola de Negócios, Pontifícia Universidade Católica, Rio de Janeiro, 164 f, 2009.

BREALEY, R.; MYERS, S. C. **Princípios de finanças empresariais**. Portugal: McGraw-Hill, 1992.

BROOKS, C. **Introductory Econometrics for Finance**. 2nd. Ed. New York: Cambridge University Press, p. 672, 2008.

CÂMARA DE COMERCIALIZAÇÃO DE ENERGIA – CCEE. Disponível em: <http://www.ccee.org.br> Acessado em: 20 fev. 2014.

______, Info Mercado, n. 80, abril, 2014. Disponível em: <http://www.ccee.org.br/portal/faces/pages_publico/quem-somos/informacoesmercado/info_mercado> Acessodo em: 29 abril 2014.

CAPORAL, A.; BRANDÃO, L. E. T. Avaliação de uma Unidade de Geração de Energia Através da Teoria de Opções Reais. **Brazilian Business Review**, v. 5, n. 2, p. 108-127, 2008.

CERVI, R. G., ESPERANCINI, M. S. T. e BUENO, O. C., Viabilidade Econômica da Utilização do Biogás Produzido em Granja Suínícola para Geração de Energia Elétrica, **Revista Engenharia Agrícola**, v. 30, n.5, p. 831-844, 2010.

COSTA, A. P. R.; NOSSA, V.; TEIXEIRA, A. M. C.; TEIXEIRA, A. J. C. Otimização de custos do transporte público urbano: comprar ou vender um ônibus usado?. **Revista de Gestão, Finanças e Contabilidade**, v. 4, n. 2, p. 73-92, 2014.

DIAS, M. A. G. **Investimento sob incerteza em exploração & produção de petróleo**. Rio de Janeiro. Dissertação (Mestrado). Pontifícia Universidade Católica do Rio de Janeiro, 1996.

DIAS, M. I. A., COLEN, F., FERNANDES, L. A., SOUZA, R. M., BUENO, O. C. Viabilidade econômica do uso do biogás proveniente da suinocultura, em substituição a fontes externas de energia. **Energia Agrícola**, Botucatu, v. 28, n. 3, p. 155-164, 2013.

DIXIT, A. K.; PINDYCK, R. S. **Investment under uncertainty**. Princeton: Princeton U. P, 1994.

EMPRESA DE PESQUISA ENERGÉTICA – EPE. Plano Decenal de Expansão de Energia 2019. Rio de Janeiro, 2010. Disponível em: <http://www.epe.gov.br/Paginas/default.aspx>. Acesso em 16 abr. 2014.

ENNES, S. A. W., Privatização do Setor Elétrico: de volta ao futuro ou um passo para o passado?, **Revista de Administração de Empresas**, v. 35, n. 1, p. 17-22, 1995.

FERRAREZ, A. H.; FILHO, D. O.; TEIXEIRA, C. A. Independência energética de granja suinícola a partir do uso de biogás. **Engenharia na Agricultura**, v. 18, n. 3, p. 248-257, 2010.

FERRAZ, J. M. G.; MARRIEL, I. E. **Biogás: fonte alternativa de energia**. Sete Lagoas, EMBRAPA-CNPMS, Circular técnica, v. 3, 27 p., 1980.

GOMES, A. C. S., et al, **O Setor Elétrico**, BNDES 50 anos – Histórias Setoriais, dezembro, 2002.

GOMES, L. L. e LUIZ, I. G., Valor Adicionado aos Consumidores Livres de Energia Elétrica no Brasil por Contratos Flexíveis: uma abordagem pela teoria das opções reais, **Revista Eletrônica de Administração**, e. 63, v. 15, n. 2, p.307-333, 2009.

GRIFFES, P.; HSU, M.; KAHN, E. Power Asset Valuation: Real Options, Ancillary Services, and Environmental Risks. **The New Power Markets: Corporate Strategies for Risk and Reward**, Risk Books, London, UK, p. 103-125, 1999.

GUEDES, A. L. e FONSECA, A. C. P. D., Privatização e Investimento Externo Direto no Setor de Energia Elétrica. In: Encontro da Associação Nacional dos Programas de Pós-graduação em Administração, 31, 2007. **Anais...** Rio de Janeiro: Anpad, 2007. CD-ROM

GUSMÃO, M.M.F.C.C. **Produção de biogás em diferentes sistemas de criação de suínos em Santa Catarina**. 2008. 170 f. Dissertação (Mestrado em Engenharia Ambiental) - Universidade Federal de Santa Catarina, Florianópolis, 2008.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, Pesquisa de Pecuária Municipal 2012, 2012. Disponível: <ftp://ftp.ibge.gov.br/Producao_Pecuaria/Producao_da_Pecuaria_Municipal/2012/tabelas_pdf/tab04.pdf>. Acesso em: 25/05/2014.

JELINEK, T. Collection, storage and transport os swine wasters. In: TAIGANIDES, E.P. **Animal wastes**. Essex: England Applied Science. p. 165-74, 1977.

KONZEN, E. A. **Avaliação quantitativa e qualitativa dos dejetos de suínos em crescimento e terminação, manejados em forma líquida**. 1980. Dissertação (Mestrado), Universidade Federal de Minas Gerais, Belo Horizonte, 58 f, 1980.

LEITE, A.L.S.; SANTANA, E.A. Mercado de capacidade: uma alternativa para o setor elétrico brasileiro. **Revista de Desenvolvimento Econômico**, Ano VIII, n. 14, p.23-33, 2006.

LOSEKANN, L. The second reform of the Brazilian electric sector. **International Journal of Global Energy Issues**, v. 29, n. 1, p. 75-87, 2008.

MADDALA, G. S.; KIM, I. M. **Unit Roots, Co Intergration and Structural Change**. Cambridge University, New York, 1998.

MARTINS, F. M.; OLIVEIRA, P. A. V. Análise Econômica da Geração de Energia Elétrica a partir do Biogás na Suinocultura, **Revista Engenharia Agrícola**, v. 31, n.3, p. 477-486, 2011.

MELO, A.C.G. Competitive Generation Agreements in Latin American Systems with Significant Hydro Generation – The Brazilian Case. **IEEE Power Engineering Review**, 1999.

NOGUEIRA, L. A. H. **Biodigestão: a alternativa energética**. Nobel, 1986.

MYERS, S. C. Determinants of corporate borrowing. **Journal of financial economics**, v. 5, n. 2, p. 147-175, 1977.

OLIVEIRA, D. L. **Avaliação de Projeto de Cogeração a partir de Biomassa Florestal: Uma Abordagem pela Teoria de Opções Reais**. (Dissertação de Mestrado) Departamento de Administração, Rio de janeiro: Pontifícia Universidade Católica do RJ, 2012.

OLIVEIRA, P. A. V. et al. **Manual de manejo e utilização dos dejetos de suínos**. Embrapa-CNPSA. Documentos, 1993.

OLIVEIRA, P.A.V. de; HIGARASHI, M.M. **Geração e utilização de biogás em unidades de produção de suínos**. Concórdia: Embrapa Suínos e Aves, 2006.

OPERADOR NACIONAL DO SISTEMA – ONS. Disponível em: <http://www.ons.org.br> Acessado em: 16 fev. 2014.

PALOMINO, J. M. G. **Formação de preço de energia elétrica gerada por biomassa no Ambiente de Contratação Livre brasileiro: uma abordagem computacional baseada em agentes**. (Dissertação de Mestrado) Departamento de Economia, Faculdade de Economia, Administração e Contabilidade de Ribeirão Preto da Universidade de São Paulo, São Paulo, 2009.

ROSA, L. P. Hydroelectric, Thermal and Nuclear Generation, **Estudos Avançados**, v. 21, n.59, 2007.

SANCHES, C. S. **Mecanismo de desenvolvimento limpo do protocolo de Quioto: há perspectivas para o setor sucro-alcooleiro paulista?**. 300 f. Tese (Doutorado) – Escola de Administração de São Paulo, Fundação Getúlio Vargas, São Paulo, 2003.

SEIXAS, F. J. M; PASCHOARELI JR, D.; FARIA JR, M. J. A. Impacto da utilização de inversores em sistemas de geração distribuída sobre equipamentos rurais. Coletânea **de Artigos: energias solar e eólica**. 2. Rio de Janeiro: CRESESB, 2005.

SGANZERLA, E. **Biodigestor: uma solução**. Agropecuária, 1983.

ZANATTO JR. C.; TEIXEIRA, D. **Conexão de cogeradores aos sistemas de distribuição - Barreiras no acesso e sugestão de regulação**. UNICA - União da Indústria de Cana de Açúcar, 50 p., 2011.