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Switching outputs in a bioenergy cogeneration project: A real options approach

Denis Luis de Oliveira [a], Luiz E. Brandao [b], Rafael Igrejas [b,*], Leonardo Lima Gomes [b]

[a] Comercial Department of Diferencial Energia Ltda, ZIP: 04544-000, São Paulo, SP, Brazil
[b] Center for Research in Energy and Infrastructure, Business School, PUC-Rio University, ZIP: 22451-900, Rio de Janeiro, Brazil

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ABSTRACT

Environmental concerns have stimulated the search for economically feasible renewable energy projects. One such alternative is the use of biomass for energy generation, which has increasingly been the focus of interest. Traditional valuation methods, on the other hand, fail to capture the value of the embedded options that exist in many of these projects, which may lead to non-optimal investment decisions. In this article we analyze the feasibility of installing a cogeneration unit in an industrial plant in Brazil in order to extract value from biomass residue currently discarded, which can be used for thermal and electric energy generation. The cogeneration unit also allows the firm the flexibility to optimally choose between an increase in production or the generation of surplus energy for sale in the short term market, once additional investment in interconnection to the grid is made. We model the uncertainty over future energy prices as a mean reverting process with jumps and seasonality and the embedded flexibility as a bundle of European options under the real options approach. The results indicate that the investment in the cogeneration plant is warranted and that the option to switch outputs adds significant value to the project, which suggests that biomass residue may be a sustainable energy alternative in this case.

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1. Introduction

Environmental concerns regarding the use of conventional sources of energy have stimulated the search for renewable and cleaner alternatives. One possible solution is the use of biomass which may be able to provide up to eight times the current demand for primary energy up from the current 14% [1]. Biomass can be defined as any renewable resource derived from animal or vegetal organic matter which can be used for energy generation [2].

Within this context, Brazil is particularly well positioned to develop a significant biomass energy generation program as its temperate climate and large availability of arable land, fresh water and sunshine provide the necessary conditions for a competitive development of biomass energy on a large scale. In addition, there is an urgent need to diversify the energy matrix of the country which is highly dependent on hydro sources and thus reduce the risks of energy shortages in years of insufficient rainfall, such as

* Correspondence to: Center for Research in Energy and Infrastructure, Business School, PUC-Rio University, CEP: 22451-900, Marquês de São Vicente 225, Gavea, Rio de Janeiro, Brazil. Tel.: +55 21 2138 9351.
E-mail addresses: denis.oliveira@diferencialenergia.com.br (D.L. de Oliveira), brandao@iag.puc-rio.br (L.E. Brandao), rafael.igrejas@iag.puc-rio.br (R. Igrejas), leonardolima@iag.puc-rio.br (L.L. Gomes).

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occurred in 2001. This has led the government to create the Proinfa feed in program for small scale energy generation which resulted in 144 new ventures with a total capacity of 3300 MW, of which 685 MW is from biomass [3].

Brazil has one of the largest forest coverage in the world. This includes 6.5 million ha of high yield commercial planted forests due to a favorable climate and a continuing research program conducted by Brazilian Enterprise for Agricultural Research (EMBRAPA), a government research center affiliated with the Brazilian Department of Agriculture [4]. Nonetheless the feasibility of these projects requires extensive logistics planning in order to minimize transportation costs, and for this reason, most of these projects are located close to the biomass source. Additionally, biomass sourced energy projects typically incorporate various embedded options, such as the flexibility to choose the optimal input source, processing method or output depending on current market conditions. While these options may add value to the project, traditional valuation methods fail to capture their impact on the feasibility of the project, which may lead to non-optimal investment decisions.

Currently there are 447 biomass power plants in operation in Brazil with an installed capacity of 9900 MW, mostly from sugarcane bagasse. More recently, in August 2013 two wood biomass projects with a combined capacity of 300 MW supplied by 55,000 ha of dedicated eucalyptus forest farms won for the first time a 25 year energy auction contract [5].

Eucalyptus biomass presents several competitive advantages. It can grow over a wide variety of soils, especially degraded pastures or lands of low economic value and across different regions of the country, and thus be an important driver of growth that does not compete with the use of land for food crops or livestock. Given that production costs are mostly in local currency, it is also not subject to exchange rate risk compared to other thermal energy sources such as coal and gas. In addition, Eucalyptus biomass is environmentally friendly, has high energy density, is easy to stock, is non-perishable and the energy generation technology is well known.

Another industrial use of Eucalyptus is as a source of raw material for the production of medium density fiberboard (MDF) wood panels. In this industry a significant amount of residue is generated during the mechanical, physical and chemical processing of the eucalyptus trees, both in the field and in the factory. Residues such as leaves, branches and undersized or low quality logs are left over during the extraction process can amount for up to 20% of the total mass of the tree, while further processing during the production phase can add another 20–30% to the total residues depending on the end product. Part of this low value residue is used as fuel for the generation of the thermal energy required for the production process and the surplus is discarded. In addition to thermal energy, the plant also requires electric energy which is usually purchased from the local utilities company and which represents a significant portion of the final cost of the product [4].

In this paper we analyze the economic feasibility of investing in a cogeneration unit to produce electrical and thermal energy from forestry biomass residues for an MDF wooden panel plant, which complemented by natural gas, allows the plant to be self-sufficient in its energy needs. The cogeneration plant would also allow the wood chips currently used for thermal power generation to be directed to other uses of higher aggregated value such as MDF panel production or the generation of surplus energy that can be sold on the short-term market, once additional investment in grid interconnection is made.

The firm benefits from this investment in two ways. First, by saving on the purchase of electric energy since the unit is now energy self-sufficient. Second, from the managerial flexibility to choose the best alternative use for the wooden chips either for the manufacturing of wooden panels or for the generation and sale of electrical energy. The flexibility to switch outputs depending on market conditions in order to maximize returns has option like characteristics, and we analyze this case under the real options approach. This flexibility also allows the firm to diversify its revenue sources and incorporate a new business model to its operations.

We assume that the main project uncertainty is the highly volatile price of electricity, as it represents one of the major input costs of the plant and, once the cogeneration unit is in place, also a potential source of revenues. Due to the strong hydro portion of the electrical energy supply in Brazil and its dependence on rainfall, electrical energy prices also show a distinct seasonal behavior. Thus, we model the short term electricity prices as a mean reverting process with jumps where we incorporate into the model the impact of seasonal factors in the price volatility, which to the best of our knowledge is an original contribution. We also assume that the optimal chip use can be decided independently on a monthly basis under a short term contract, which allows this flexibility to be modeled as a bundle of European options and we solve with a Monte Carlo simulation under the risk neutral measure.

Real options theory has been widely used to analyze renewable energy projects [6–10]. Venetsanos et al. [11] applied real options analysis to value power generation projects from renewable energy sources within the newly deregulated electricity market in Greece. Kjærland [12] presents an assessment of renewable investments in Norway using the Dixit and Pindyck [13] real options approach and analyze the relation between optimal decision to invest in hydropower plants and electricity price level. Kumbaroglu et al. [14] developed a dynamic programming framework based on real options approach, to assess investments flexibilities of different renewable generation technologies of the Turkish electricity market. The diffusion and competitiveness of these technologies are impacted by uncertainties which could not be modeled by the traditional valuation techniques as the discounted cash flow method.

Araujo et al. [15] show that the upgrade in cogeneration equipment in a sugarcane processing plant adds flexibility and value to the firm. Arenaro et al. [16] analyze a sugar and ethanol production plant in Brazil which has the option to expand capacity and add a cogeneration plant that would allow the firm to sell surplus energy into the grid, where commodity and energy prices are modeled as a mean reverting diffusion process. Tolis et al. [17] investigated the economic aspects to handle in a more effective way with the problems arising from the stochastic nature of significant cash flow contributors' evolution like electricity, fuel and CO_2 allowance prices, using the real option method in a comparative model of locally available renewable and conventional fuels. They also indicate that many renewable energy projects have embedded flexibilities that can only be modeled and valued under option pricing methods. Martínez-Ceseña and Mutale [18] developed an advanced real options methodology to assess renewable energy generation project planning, considering as case study a hydropower plant using a dynamic programming model to determine the optimal decision of investment timing and project design. The authors also used Monte Carlo simulation to calculate the expected project value under uncertainty when implementing the investment and conclude that real options modeling can improve the economic analysis of renewable energy projects.

Although there is an extensive literature on the application of real options in renewable energy projects, the use of switch option models is still scarce. Bastian-Pinto et al. [19] provide a valuation of the flexibilities available in a sugarcane mill which can optimally switch production between sugar and ethanol, depending on market conditions. In a similar fashion, Brandão et al. [20] show that the diversity of inputs available for the production of biodiesel provides valuable input switch options. Detert and Kotani [21] addressed the investment decision under uncertainty considering the switch between the continuing use of coal generation system and renewable energy power