***TECHNICAL AND FINANCIAL ASSESSMENT OF INDUSTRIAL ENERGY MANAGEMENT: AN APPROACH BASED ON REAL OPTIONS***

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# Overview

Electricity consumption has always been one of the indicators of economic development and the level of quality of life in any society, as it reflects both the pace of activity in the industrial, commercial and service sectors, as well as the population's ability to purchase goods and services, technologically more advanced. However, climate change is leading humanity to seek new energy sources and new technologies that reduce energy consumption without harming its development.

Given the growing demand for electricity worldwide, added to the challenge of finding a more efficient way to consume electricity without losing sight of the economic and financial viability of projects, there is a scarcity of models in the literature that lead to account for these issues for the implementation of energy management projects. In these projects, in addition to the quest to reduce energy consumption, the uncertainties linked to the investment must be considered for the decision-making between investing in or abandoning them.

This work aims to propose a model for the technical-financial evaluation of an energy management project based on the use of distributed generation with renewable sources and energy efficiency actions. The conceptual model developed to achieve this objective combines modern tools for economic-financial assessment, Real Options, and methodologies for Measurement and Verification (M&V) of the performance of energy efficiency projects through studies with time series and dynamic regression models for modelling the baseline.

# Methods

Measurement and Verification (M&V) methods are pivotal for Energy Conservation Services Companies (ESCOs) when presenting energy management projects to potential clients. The energy management system, incorporating periodic reviews, focuses on projects like energy efficiency, supply-side management, and distributed generation. Implementing M&V processes involves determining a baseline, aiming to estimate the conserved energy; the use statistical models such as linear regression to quantify energy savings.

The International Performance Measurement and Verification Protocol (IPMVP) and ASHRAE Guideline 14 provide comprehensive guidelines for M&V processes, ensuring reliable results through statistical metrics like the coefficient of variation of the root mean square error (CV(RMSE)) and the coefficient of determination (R²). These metrics address uncertainties associated with baseline models, emphasizing transparency and minimizing uncertainty for robust energy management projects.

Investment analysis in the industrial sector emphasizes methodology like Real Options as relevant for decisions extending beyond one period and replacing traditional methods like Discounted Cash Flow. It considers flexibility, crucial for modelling uncertainties in the M&V process. Understanding risk and uncertainty is pivotal, with three types identified: economic, technical, and strategic. Various approaches like decision trees, sensitivity analysis, scenario analysis, and Monte Carlo simulation address uncertainties, providing flexibility and strategic advantages in decision-making when using the Real Options approaches.

The proposed conceptual model outlines a comprehensive approach for the technical and financial evaluation of energy management projects, emphasizing distributed generation and energy conservation measures. The model comprises two phases: the first evaluates candidate projects using distributed generation and energy conservation measures, while the second conducts financial assessments through Real Options. The technical evaluation aligns with ISO 50001:2015 guidelines, considering sustainability and renewable sources on the supply side. At the same time, the financial valuation phase employs Real Options models, with the binomial model approach, providing a nuanced understanding of project risks for precise decision-making throughout the project lifecycle.

# Results

The results of the applicability of this model were obtained through its use in a real situation of evaluation of an energy management project in the pharmaceutical industry composed of two stages. The first comprises the determination of energy savings achieved through the implementation of a retrofit in the factory's HVAC system, and the second contemplates the assessment of the financial viability of a possible expansion of the energy management project with the installation of the generation photovoltaic plant.

The pharmaceutical industrial park underwent a retrofit in its HVAC system as the first stage of the energy management project, demonstrating a 4% average reduction in total energy consumption. The data, collected from 2016 onwards, includes production figures, energy consumption, and the Accumulated Degree-Day (GDA) variable. Statistical metrics confirm the effectiveness of the baseline model, with an R² of 89.68%, MAPE of 4.29%, and CV of 4.69%. The well-established baseline model allows us to show a 4% average reduction in energy consumption post-implementation of energy conservation measures.

The second stage involves planning for a distributed solar generation project, aiming to cover approximately 30% of the factory's consumption related to the HVAC system. The solar park's budget is estimated at R$10.5 million, with a monthly target generation value of 300MWh. The financial analysis, employing the Real Options approach, considers the uncertainty of energy prices using Monte Carlo Simulation. The present value of the distributed generation project is calculated at R$5,196,319.02, with an estimated volatility of 11.29%. The binomial tree and Real Options modeling showcase the feasibility of the expansion option, revealing a significant increase in value (BRL 28,160,613.48) when exercising the option, affirming the viability of the distributed generation project.

It was concluded that the proposed model allows the technical-financial evaluation adequately since the financial part of the model receives, as input, the results from the technical part of the model and when using Real Options as an evaluation method, the technical uncertainties are included in the analysis through the elaboration of the binomial tree of Real Options, making it possible to measure the value of the expansion option within a project for energy management. Therefore, it is possible to carry out a technical-financial evaluation of projects for energy management through the Real Options approach, obtaining satisfactory results with the application of the model.

**Conclusions**

Applying the proposed conceptual model for the technical-financial evaluation of energy management projects yields significant insights and demonstrates the model's potential. Firstly, practical study and project scope planning are crucial for accurate execution and financial assessment, particularly given the high investments involved. The need for evaluation methods with reduced uncertainties is underscored in this context. Secondly, the dynamic regression model proves satisfactory for Measurement & Verification, producing statistical metrics with uncertainties below 5%, indicating a robust fit to accurate data. The application of this M&V model reveals a 4% average reduction in electricity consumption resulting from the retrofit in the HVAC system. Financial valuation using the Real Options approach is highlighted, enabling decision-makers to evaluate various investment scenarios. Despite challenges in determining the actual value and risk-return characteristics due to the absence of market commercialization, the present value obtained through the expansion option indicates the feasibility of the second stage of the energy management project.

Another critical aspect is the consideration of uncertainties, which are classified into economic, technical, and strategic uncertainties. Technical uncertainties arise from the M&V of energy savings, emphasizing the importance of a well-adjusted model with low uncertainty. Economic uncertainties involve tariff and project price volatility, while strategic uncertainties pertain to the company's behaviour in the market and new investments. The Real Options approach is noted to encompass all three types of uncertainty. In conclusion, the conceptual model proves effective as a technical-financial tool for evaluating energy management projects, successfully modelling previous phases to obtain data for the financial evaluation of future project stages. However, the model has some limitations in considering all uncertainties that can be explored in future works.

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