

Investment Analysis for Energy Efficiency Management Systems in Industrial Refrigeration

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Abstract. Brazil has one of the least efficient industries in energy use when compared to other major world economies. Although it is among the largest producers of poultry in the world, the country has lost competitiveness. The pursuit of energy efficiency is in the Brazilian government plans, while it hasn't occurred effectively. This paper seeks to elucidate the requirements for creating an energy management system for the chicken slaughterhouse industry through a methodology to analyse the feasibility of implementing such system. This industry, in general, has not developed processes for energy management even after the rise of ISO 50001 in 2011. Presumably due to infeasibility to the creation of these systems. The country needs to invest in policies that promote energy efficiency, by proving the viability of investments such as energy monitoring systems or, for example, intervening in the industry through incentives.

Key words

Energy efficiency, indicators, economic feasibility, chicken slaughterhouses, refrigeration.

1. Introduction

Brazil is one of the major food producers in the world, because the national food industry is an important segment of economic activity in the country with great dynamism in manufacturing, exporting and technical progress in the production chain. Figure 1 illustrates the

top producers of chicken meat in the world.

Fig. 1. Poultry production by country [1].

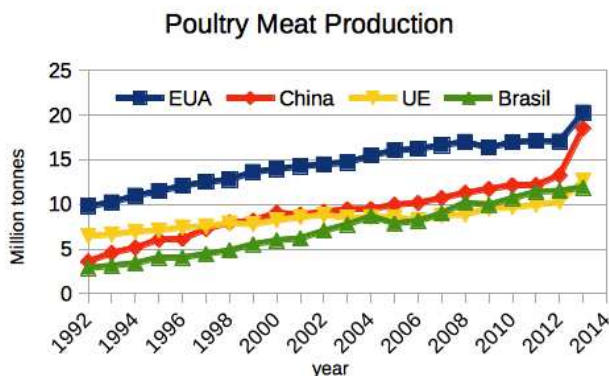
Faced with growing production of chicken meat in Brazil, one of its consequences was the increase in electricity consumption, so the industrial sector was the Brazilian great energy consumer in 2012 with 41%, followed by 26% households, 18% commercial and 15% others with a total consumption of 448 GWh [2].

Efficiency and power management are on a world stage in recent years. Energy is a strategic issue for industry, society, economy and security. So, there have been developed various policies specially designed for energy efficiency (EE), demand for renewable energy and cleaner production.

In Brazil, the national energy efficiency plan aims to reduce energy consumption by 10% over the period 2010-2030 [1]. The country is among the 10 largest consumers of electricity in the world, although its share in total (2.5%) is far from the United States (the largest consumer with 21% of the total). Although the rate of Brazilian industrial electrical energy is almost twice the value compared to the first placed [4].

Comparing 16 countries around the world because they are large economies, showed that the country is on the penultimate rank of EE, ahead only of Mexico [5]. This position is repeated in the evaluation of the industrial sector. The Brazil and Mexico are the only evaluated countries that has no voluntary agreements between government and organizations, or laws that require a professional dedicated to industrial energy efficiency programs, or even mandatory energy audits.

Energy efficiency in Brazil industry has not developed despite government efforts. According to a survey of [6], in November 2011, demonstrates that the strategy of most importance to these companies is the "customer satisfaction". When asked where will go their next



investments, 48% of entrepreneurs responded that they would invest in productivity.

The EE is not in the agenda of Brazilian industries and these organizations are not well supported with EE policies. There are few concrete policies to promote commitment of organizations with country EE goals. In addition, the industry has little information to compare their energy performance with each other and often do not know which actions they can take. Also, the refrigeration sector of the chicken slaughterhouses, which corresponds to 70% of its electricity usage, could benefit with the development of an EE management.

In this context, this paper describes indicators for monitoring EE conditions and proposes a model of economic feasibility analysis in order to promote the adoption of an energy management system (EMS) to the Brazilian chicken slaughterhouse industry, as the country is one of the largest chicken producers in the world.

2. Energy Management

The energy management is a process of planning, improvement and verification according to a management model – to ISO 50001, the PDCA (Plan-Do-Check-Act). First, it makes a survey of the energy situation of the organization (called energy review) reporting the use and consumption of energy in the organization periodically, EE goals, objectives and actions are planned.

For any energy efficiency plan is essential to identify process performance before and after improvement actions implementation, called Energy Base Line, and obtained by monitoring performance indicators.

Energy efficiency management is based in performance evaluation through indicators. The EMS implementation in the refrigeration industry ends in creating a culture of efficiency and that can be the gateway to the development of efficiency across the organization. So, later, developing a culture of financial efficiency, production and other sectors of the institution, making it more competitive.

The monitoring of energy consumption is a key part to the implementation of a EMS and is only feasible when energy efficiency indicators are monitored, which would hardly be done manually. To identify causes of inefficiencies in the manufacturing process is not an easy task without the existence of sensors capable of obtaining information about energy use.

A. Poultry Industries Cooling System

The electric bill for large slaughterhouses is an amount about a million per month, and this industry cooling system, in general, is between 60-75% of the electric bill [7]. Thus, one of the key factors for chicken slaughterhouses to avoid waste and minimize the cost of energy is control of industrial refrigeration system.

The cooling system circuit uses vapor compression in which ammonia is used as the cooling fluid, since it can

achieve extremely low pressure needed for the system temperature. Normally, cooling systems in poultry slaughterhouses are three:

- 1) *Freezing: line for cooling products, requiring ammonia cooling system temperatures around -35°;*
- 2) *Chiller: line with a temperature of -5°; and,*
- 3) *Climatisation: cooling of environments, with temperatures close to 0°.*

B. Minimum Energy Efficiency Indicators

The use of indicators is a very important tool to highlight the conditions of the cooling system and their paths to evolve. They have the property of separating the important aspects of a wide range of information and, therefore, can help in the decision-making process. Indicators are needed in monitoring, evaluation and diagnosis of the systems studied.

This paper defines five basic indicators for a first step toward managing EE in chicken slaughterhouse industry. Some indicators are monitored, as the total consumption of electricity, the cost per unit, the financial value generated and annual savings. It is understood that the minimally this industry can monitor with a little effort, these performance indicators. The first, equation (1), represents the total electrical consumption (TEC) in a period of time (kilo Watts hour per month). It is present in every industry as the electrical bill easily obtains it.

$$TEC = \frac{kWh}{month} \quad (1)$$

The second most important indicator of EE for slaughterhouses is related to the production due to industry need of production measurements. Comparing to production data there is the electricity consumption by total chicken meat production to obtain the unit cost (UC), in equation (2), represents the kilo Watts hour consumed per produced chicken meat kilograms). If there is other sources of energy than electricity, their units must be converted to a common one and added up to calculate this indicator.

$$UC = \frac{kWh}{kg} \quad (2)$$

The described indicators are important for industry EE management and controlled by the technical supervisor, however, the business owners are more interested in capital gain. The generated financial value (3), represents the transformation of values, from the total energy costs over the generated product income in monetary value.

$$GFV = \frac{\text{input energy value (\$)}}{\text{output production value (\$)}} \quad (3)$$

Finally, to complete the picture of some minimal EE management, the organization's annual reviews on total energy consumption. The annual savings in equation (4) consists on comparing energy consumption from one year to another, in kilo Watts hour.

$$AS = kWh_{year\ 1} - kWh_{year\ 2} \quad (4)$$

One of the key factors to chicken slaughterhouses avoid waste and minimize the cost of electricity, is the control of industrial refrigeration. The numbers involved in this segment are very high. So it becomes important to use a specific electrical energy panel (secondary panel) for the refrigeration sector. However, no indicators to monitor cooling system EE are used, although it consumes most of the power. Thus, the fifth indicator: **Specific Energy Consumption (SEC)**, describes the specific energy consumption of the cooling sector (SEC) in kilo Watts hour by the installed capacity (tonnes of refrigeration, TR) in cold chamber and other equipments, as in (5).

$$SEC = \frac{kWh}{TR} \quad (5)$$

The TR can be determined by knowing refrigerant temperature, pressure and mass flow rate. Measurements of temperature, pressure and mass flow are implemented in compressors inlet (suction) and power consumption measured in the compressor's switch panel for a given refrigeration line. Also, the mass flow can be determined with lower reliability, from the work characteristics of each particular compressor.

Ideally monitoring – with a sensor for each of the quantities (temperature and pressure) – could occur in two places: in the input (the compressor suction) and outlet of the compression equipment (evaporator inlet) to determine the installation's cooling capacity. However, this model can be simplified to monitor the system TR just at the entrance of the compressors and monitor the variations in the system along determined time periods.

The SEC determines the efficiency of the system (including management, maintenance, operation and deployed technology) and monitors the power consumption of the system, where high rates point to an excessive heat gain. Monitoring this indicator may indicate a problem of efficiency in the system, although it is still too shallow to find out where and what may be the problem. However, this is the starting point for a more complete monitoring of the refrigeration system.

The literature presents informations for the Brazilian industry to develop a EE process management, however, the presence of EMS in slaughterhouses is not a reality. Knowing that the industry is inefficient and that the EMS can turn them better, why is it not used? This leads to question whether the energy management system is economically feasible.

3. Financial Analysis Method

Suspecting that the use of an EMS has not occurred for financial reasons, this paper proposes a methodology for analysing financial investments for creation of energy management systems in chicken slaughterhouses cooling systems.

The use of financial resources in an enterprise is said feasible if some wealth is generated. This is justified only when the disbursement has prospects of receiving future benefits [8]. However, even if the benefits outweigh the costs, this does not necessarily mean that the investment is a good choice. The feasibility assessment of a business comprises a set of financial tools to support the decision to make an investment.

A. Data Collection

Firstly, indicators that will be measured by EMS are defined, as the system design. Subsequently, the development of a technical and economic viability study requires identifying the necessary technologies, their costs and their expected revenues. An EE monitoring system should consider acquisitions of:

- 1) **Sensing technologies** for each variable to be monitored. Being necessary to raise the following information for each sensor type: operating range, temperature range to measure, life span, model, manufacturer, quantity required and price;
- 2) **Data acquisition technologies** (equipment and control systems). Relating: type of acquisition system, manufacturer, number of inputs, number of outputs, lifetime, energy consumption, cost, quantity, and availability of a management software. With regard to choice of data acquisition system with the number of entries required by the EMS;
- 3) The sensors **distances** to the connection panel with that data acquisition system. In addition to the cost of purchasing the sensors, are included cabling costs (cables, filters and signal amplifiers). Considering: type of technology, manufacturer, life span, the amount of cable needed for each sensor and cost per meter;
- 4) **Installation costs** of such equipment. Including the payment for the professional who will do the work (internal or external to the industry), per hour.

As investments have risks, the best choice of technology should reduce the risk of choosing a feasible investment. The higher quality of this input data will give more credibility to the investment analysis.

B. Quality of Information

The quality of the input information adds reliability to the results. The economic analysis should consider measurable criteria such as profitability and risk, and other imponderable criteria as: security, easy maintenance and materials quality. In addition, the estimated values should

be accurate, not being overestimated or underestimated so the input data does not undermine the analyst decision.

Among ponderable data, are the implementation costs: acquiring sensors, cabling and data acquisition systems, installation and data analysis software. Besides, the operation costs, consumption and equipment depreciation, as well income taxes and others. On the other hand, certain imponderable events qualify the analysis, but not being quantifiable, must be specified to support the analyst decision. This may include: the availability of equipment and trained professionals, company investment priorities and leaning to take risks. Imponderable criteria are considered as, in some cases, the viable alternative indicated by quantitative data is not the best option.

C. Investment Analysis

Sequent to data collection with financial data for the EMS implementation and operation, it begins the investment analysis considering the cost projections for one or more investment alternatives. For any financial analysis it is known that the present values have different meaning in the future, that is, goods that can be acquired with a specific monetary value on current date are not the same as if bought at a future date. So the monetary values of an investment over time cannot be compared as equals.

Furthermore, it is understood that for any investment, the decision to not employ resources in some enterprise means that these same resources will be applied to another type of investment, as savings. So the projections of costs and revenues of the EMS project should have discounted the value of a Minimum Rate Attractiveness (MRA), i. e., the rate at which the money would be invested if the project was not implemented. It is recommended that the costs, benefits and balance of the projected cash flow are recapitalized on a savings average rate in the last 12 months, to be used as MRA. However, if the MRA industry in question is known, it should be used to add reliability to the decision.

For the cash flow projection of this investment, first must be compiled the investment costs in each time period, including the initial investment. Revenue projections will simulate percentage savings compared to the total monthly energy costs. The analysis need to consider values of minimum monthly savings needed to total energy costs that make it a viable investment. Since this type of investment there is no inflow of capital, it considers as revenue the saving provided by the cooling system when being constantly monitored.

In order to increase the reliability of the decision, it is proposed the use of different indicators related to return on investment, risk and the project sensibility to become unviable.

The first indicators group is related to the return of investment, as it inflict profit or not:

- 1) **Present Value (PV):** being positive, indicates that the benefits outweigh the costs (there is profit in investment). The PV is the monetary

values in financial analysis subtracted the MRA in each period, thus arriving at their present value;

- 2) **Net Present Value (NPV):** is the VP, including the initial investment. The positive value of NPV is that the project pays its initial investment, the income of TMA and there is a remaining cash excess;
- 3) **Annualized Net Present Value (ANPV):** NPV represents the period of one year as projects with different planning periods can not be compared by NPV, so it becomes necessary to compare the projects in the same periods. This indicator is the NPV evaluated annually (cash excess per year);
- 4) **Index of Benefit / Cost (IBC):** gain per unit of invested capital, so it must be greater than one for the project to be profitable;
- 5) **Economic Value Added (EVA):** additional gain on investment, considers that the capital available for investment would have the application of MRA and the EVA represents the additional gain. Represents the percentage return per period beyond the MRA;
- 6) **Index EVA / MRA:** percentage of earnings beyond the MRA for the entire project;
- 7) **Return on Investment (ROI):** investment return rate per period (month) for the project implementation. Can be directly compared to the MRA.

The second group of indicators are related to project risks. In other words, they describe project risk of become impracticable in relation to their income and return on investment over time.

- 1) **Payback:** period of investment payback. Its the number of periods (months) at which revenues exceed costs;
- 2) **Internal Rate of Return (IRR):** rate of return on investment is the rate where the project cash flow has zero NPV. The higher IRR relative to MRA, the better the investment and its risk increases proportionally as the IRR approaches the MRA;
- 3) **Index Payback / N:** project risk not achieving return. Compares the project payback to the projects planning horizon (N), i. e., the project total period of execution;
- 4) **Index MRA / IRR:** percentage gain of TMA compared to IRR.

The third group of indicators point to the investment sensibility of becoming unviable in order to demonstrate the impact that variations in costs and revenues have on the feasibility of the project.

- 1) **MRA Variation:** percentage limit the MRA can increase and investment would remain viable;
- 2) **Costs Variation:** percentage threshold at which costs may increase and investment would remain viable;
- 3) **Change in Revenue:** percentage threshold at which benefits can reduce and the project would remain viable.

These indicators are proposed for a more complete financial analysis aiming to ensure that the decision to invest in the project is and will remain viable. Further details and equations can be found in [8]-[10].

4. Conclusion

This paper aims to provide tools for the development of a more efficient industry in Brazil, where it has low performance in energy use. Encouraging chicken slaughterhouses to develop an EMS, if this is demonstrably feasible or, if not, encourage the creation of government policies and incentives to meet national efficiency plan that prospects a reduction of energy use by 10% by 2030.

The investment analysis for an EMS depends on a good system design. Financial tools can provide insight of the project feasibility, however, much depends on the industry assessment of the capacity to being reached great scales of economy in the cooling system. The electricity cost in the chicken slaughter is only 2.69% of the cost per kilogram of chicken meat, this indicates the low representativeness that energy costs have on the product final price and may explain this industry lack of interest to invest in EE.

The country needs to invest in policies that promote energy efficiency, by proving the viability of investments such as energy monitoring systems or, for example, intervening in the industry through incentives such as funding, tax reduction, financial support, energy audits and professional training.

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