Energy Savings Resulting from Energy Management Program Using Measurement and Verification Procedure

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Abstract. Energy efficiency is one of the main solutions for problems such as the increase in energy consumption and greenhouse gas emissions. Energy savings are obtained by the increase of efficiency, a solution that reflects directly on the energy matrix, lowering the amount of gases emitted during energy generation. According to the available literature, there are many works that deal with existing equipment exchanges for more efficient ones. The aim of this article is to show the effectiveness of the energy efficiency program in saving energy, showing how the amount of energy reduced is proven and discussing the accuracy errors. The case study is a resort in Rio de Janeiro - Brazil. In order to prove the energy saved, measurement and verification models were built according to recommendations in international protocol (IPMVP) and standards (ISO 50001, GUM).

1. Introduction
Studies point out that the excessive emission of greenhouse gas – GHG can cause global warming, which is responsible for climate changes [1]. One of the major GHG emitter are coal-fired power plants, which are also one of the major sources of electric power in the world. This scenario is aggravated by an increasing demand for energy, due to changes in the consumption profile with the advent of new technologies. [1]

To make available more energy and, at the same time emitting less GHG, one can use alternatively renewable energy sources or simply make consumers more efficient. Thus, it is possible to save energy that can be used for other purposes, or even to withdraw the obligation of generating energy by the power plants that pollute the energy matrix of a country.

This article aims to detail, through a case study, the amount of energy savings achieved by energy management in the commercial sector. An energy efficiency work carried out by an Energy Service Company (ESCO) at a Resort located in state of Rio de Janeiro will be used for this study.

In order to prove the savings, data collected from the energy bills, energy performance improvement actions (EPIA) and diesel generator dispatch data were used in conjunction with International Performance Measurement and Verification Protocol (IPMVP)[2], ISO 50001[3], ISO 50002[4] and ISO 50015[5]. These documents include good practices in energy audits, measurement and verification (M&V) and establish minimum requirements of precision and confidence to measure the real savings obtained after the EPIA.
2. Case Study

This article is based on a case study, using real data and analyzing an energy efficiency work carried out by an ESCO at a resort in the state of Rio de Janeiro. For confidentiality reasons stated in the contract, names of both the parts are going to be omitted.

The resort has 5 power meters, one in each substation, with an area of 137.068 m². In the main substation named SEDE, which is the largest consumer, are connected restaurants, event venues and the hotel lobby. In the substation named Apartments – APTO, 150 hotel rooms are connected. This is the second largest consumer. CANTINA is the substation responsible for feeding the maintenance area, warehouse and employees’ cafeteria. At last, the SPA substation feeds massage rooms, saunas and the administrator’s residence.

The ESCO was hired by the customer in February 2016, to develop an energy audit at its facilities in order to find energy performance improvement actions (EPIA) that would reduce the hotel's energy consumption.

In the audit accomplished, following the precepts of ISO 50002 that guides the requirements for the performance of an energy audit, it was verified that the Energy Performance over the total annual cost of the use of energies was of R$ 1,056,572.43 (base year 2015). It was also estimated that a set of energy efficiency measures (EEM) would save around 9.27%, which corresponds to R$ 98,256.91 per year. This value was found prioritizing equipment exchanges that should be made by the client.

During the step of collecting data, it was noticed that the external temperature and the occupation of the hotel were independent variables that highly influenced the energy consumption. This influence was proved by the correlational method between these variables and the energy measured constantly in bills.

One year after the start of the energy management program, the ESCO noticed that because of alterations and cuts in the investments of new efficient equipments that were needed to reduce cost, there was a big risk that initial savings predictions wouldn’t be reached. On the other hand, the energy bills showed different. During the monitoring and after the engineering technical team critical analysis, savings of R$ 51,315.16 were estimated until December of 2016.

Four possible EPIA responsible for the savings generated by the energy management program were pointed out:

- Changes in the operation of the diesel generator, monitoring the peak load, and reducing the usage of energy from the electricity distribution utility;
- Adjustment of the energy meters’ clock, which was desynchronized with Brasilia time, charging as consequence a high tariff when it was still off-peak time;
- Adjustment in the capacitor banks.

From May 2016 to mid-October 2016, a nonconformity on the capacitor bank panels was corrected. These panels were installed without the ESCO’s supervision and were poorly configured. Instead of correcting the inductive reactive energy they were producing at the time where the energy is usually capacitive, thus generating billing. The ESCO intervened in the month of October to correctly parameterize the bank of capacitors as to the time of entry and its capacitive load.

The resort’s energy bills are charged according to the “Green Time” type of tariff. This means that there are two energy consumption tariffs divided into consumption at on-peak hours (from 6:00 pm to 9:00 pm) and consumption at the off-peak hours. There is also a charge for contract demand. The hotel also has generator sets to work as the power source at peak times. The savings over the contract demand optimization will not be accounted for in this study.

3. Proof of Energy Conservation

As a matter of proving the energy savings, the ISO 50006 and ISO 50015 standards were used along with the International Performance Measurement and Verification Protocol (IPMVP) and the Guide to Expression of Uncertainty in Measurements (GUM) [6]. This set of standards guides the rules for
Measurement and Verification (M&V), in order to prove the savings generated by the EPIA implemented. According to the family of Standard ISO 50001 and the IPMVP there is no way to directly measure energy savings, for this it is necessary to create a mathematical model called the baseline, which reproduces the behavior of the energy consumption before the EPIA occurs in the post-period Implementation of the EPIA. And with this baseline and measurement values after EPIA, it is possible to estimate the energy savings.

For a good baseline, the IPMVP recommends that the coefficient of determination ($R^2$) should be at least 0.75, the coefficient of variation (CV) of 20% at most and the coefficients resulting from the linear regressions should have a t-statistic greater than 2. It is also specified that a minimum precision of 10% shall be used for a 95% confidence level, if sampling is required.

For the case study, although the savings are still not fully measured and the EPIA are not fully implemented, it is wanted to find energy savings that are consequences of low cost energy management actions. Therefore, Method C from IPMVP will be used to prove the economy. This method uses the distribution utility meter. Other methods use specific measurements for each equipment/systems (method A and B) or perform consumption simulations (method D).

For the application of method C there is the restriction that the total energy saved should be greater than 10%. If the total economy is less than 10%, it should be checked whether the EPIAs are well spread so that individualized measurement is not possible. As the hotel case study the EPIAs are largely in the awareness of people, it is not possible to carry out the individualized measures, thus being method C most appropriate to carry out the M&V process.

Since several baselines will be carried out, one for each item (on-peak and off-peak time consumption, demand, and generator usage), and since each energy efficiency action affects different items, in this work they will be unified, converting their values to a unit that is common to all variables: money. Thus, it will be easier to perceive the final savings. In this way, the measurement uncertainties will be combined to find general precision.

The variables used to build baselines for the commercial sector of hotel industry are commonly the temperature and occupation of the consumer unit. The temperature is collected from the official meteorological websites and the occupation can be taken directly with the hotel’s manager. Later, the data is adjusted to match the billing days.

### 4. Results

As a result, 5 baselines models were built: equation (1) the consumption of electric energy in off-peak hours, equation (2) demand, equation (3) the consumption of reactive electric energy, equation (4) the consumption of electric energy in on-peak hours, and equation (5) consumption of liters of diesel in the generator used at peak hours. The baseline equations are shown in table 1, the statistics resulting from the regression process are shown in table 2, which can be seen in t-statics the parameters are significant. Energy consumption, ambient temperature and hotel occupancy data were used considering the horizon from 2015 to 2016. These data can be found in table 3.

| Consumption of energy utilities                      | Linear regression equation. |
|------------------------------------------------------|-----------------------------|
| Electric energy in off-peak hours [kW h]             | $1456,88 \times temp_i + 1283,42 \times occu_i - 130,51$ (1) |
| Demand [R$/kW]                                       | $1283,42 \times occu_i + 11,68$ (2) |
| Reactive electric energy [R$/kV A h)]               | $240,69 \times temp_i - 53,00 \times occu_i - 37,85$ (3) |
| Electric energy in on-peak hours [R$/kW h]          | $100,45 \times occu_i - 491,61$ (4) |
| Liters of diesel [L]                                | $123,51 \times temp_i - 183,27$ (5) |
Table 2 – Table of the statistical results of linear regression.

| Energy Utilities                              | Baseline Period            | T-statistic Temperature Coefficient | T-statistic Occupation Coefficient | $R^2$ | CV  | Standard Error (RS) |
|-----------------------------------------------|----------------------------|-------------------------------------|-----------------------------------|-------|-----|---------------------|
| Electric energy in off-peak hours [kW h]     | From jan/15 to jun/16     | 2,58                                | 4,23                              | 0,99  | 12,4% | R$ 8.162,01         |
| Demand [kW]                                   | From jan/15 to jun/16     | -                                  | 24,66                             | 0,97  | 17,5% | R$ 329,70           |
| Reactive electric energy [kV A h]            | From jun/15 to abr/16     | 6,33                                | -2,63                             | 0,97  | 20,3% | R$ 495,64           |
| Electric energy in on-peak hours [kW h]      | From jun/15 to abr/16     | -                                  | 16,72                             | 0,97  | 20,3% | R$ 1,048,78         |
| Liters of diesel [L]                         | From jan/15 to abr/16     | 16,61                               | -                                 | 0,97  | 22,0% | R$ 754,26           |

Table 3 - Consumption data table of energy utilities and independent variables used for baseline and energy saving calculations.

| Date   | Electric energy in off-peak hours [kW h] | Demand [kW] | Reactive electric energy [kV A] | Electric energy in on-peak hours [kW h] | Liters of diesel [L] | Temperature [°C] | Occupation [%] |
|--------|------------------------------------------|-------------|---------------------------------|-----------------------------------------|----------------------|-----------------|----------------|
| jan/15 | 166739                                   | 494         | 3954                            | 11786                                   | 2609                 | 36,3            | 86,8           |
| fev/15 | 140133                                   | 524         | 4314                            | 11347                                   | 2363                 | 30,3            | 79,4           |
| mar/15 | 135912                                   | 503         | 3991                            | 11815                                   | 2861                 | 31,2            | 55,4           |
| abr/15 | 110355                                   | 404         | 4901                            | 10568                                   | 2878                 | 28,1            | 40,1           |
| mai/15 | 99141                                    | 370         | 6062                            | 9486                                    | 3227                 | 29,0            | 48,2           |
| jun/15 | 79107                                    | 281         | 5149                            | 4427                                    | 3289                 | 26,9            | 36,9           |
| jul/15 | 72744                                    | 345         | 4995                            | 5081                                    | 3331                 | 26,8            | 42,7           |
| ago/15 | 95970                                    | 307         | 4933                            | 5964                                    | 3277                 | 29,6            | 48,6           |
| set/15 | 84546                                    | 274         | 4711                            | 5262                                    | 2539                 | 28,1            | 42,6           |
| out/15 | 89335                                    | 327         | 4766                            | 6394                                    | 2428                 | 28,4            | 51,2           |
| nov/15 | 113715                                   | 370         | 4505                            | 6870                                    | 3301                 | 33,2            | 58,9           |
| dez/15 | 101598                                   | 378         | 3385                            | 4216                                    | 3805                 | 31,8            | 54,2           |
| jan/16 | 157479                                   | 486         | 3870                            | 5873                                    | 4502                 | 33,3            | 73,8           |
| fev/16 | 145698                                   | 482         | 3582                            | 5782                                    | 4878                 | 34,1            | 71,9           |
| mar/16 | 115857                                   | 416         | 3157                            | 5765                                    | 4541                 | 28,8            | 57,5           |
| abr/16 | 122430                                   | 407         | 4219                            | 4934                                    | 4997                 | 31,5            | 47,1           |
| mai/16 | 106428                                   | 419         | 8993                            | 3442                                    | 3898                 | 25,9            | 40,5           |
| jun/16 | 93954                                    | 310         | 14553                           | 3166                                    | 3300                 | 25,5            | 36,9           |
| jul/16 | 89397                                    | 326         | 16925                           | 4432                                    | 3221                 | 28,7            | 45,3           |
| ago/16 | 88725                                    | 290         | 4830                            | 3677                                    | 3328                 | 25,7            | 46,2           |
| set/16 | 95571                                    | 311         | 4369                            | 948                                     | 4135                 | 28,8            | 47,4           |
| out/16 | 90510                                    | 373         | 2222                            | 1795                                    | 4381                 | 25,5            | 51,0           |
| nov/16 | 105168                                   | 383         | 1389                            | 1143                                    | 5326                 | 24,8            | 56,9           |
| dez/16 | 1113190                                  | 389         | 0                               | 1114                                    | 5481                 | 24,8            | 57,0           |
For the measurement uncertainty calculation, because of the diversity of measurement units, the standard errors found were converted to monetary value using the respective tariffs, which can be seen in table 4.

Table 4 - Energy utilities tariff table

| Year | Electric energy in off-peak hours [R$/kW h] | Demand [R$/kW] | Reactive electric energy [R$/kW A h] | Electric energy in on-peak hours [R$/kW h] | Liters of diesel [R$/L] |
|------|------------------------------------------|----------------|-------------------------------------|------------------------------------------|------------------------|
| 2015 | 0,48                                     | 24,66          | 0,39                                | 2,20                                     | 2,73                   |
| 2016 | 0,53                                     | 26,58          | 0,39                                | 2,42                                     | 3,02                   |

The result of crossing the actual consumption energy measurements, and baseline in the period of economy are shown in figure 1. This is the graph of total monthly expenditure, in Reais, adding up all utility expenses in each month. Then, it is possible to identify: (a) the energy measurements used to calculate the baseline until the arrival of ESCO, (b) the baseline in the period of measurement of the economy, representing what would be the consumption without the application of the EPIA (c) energy measurements after the EPIA, i.e. after the entry of ESCO. Making the difference between (c) and (b) is found monthly energy savings.

![Figure 1](image)

**Figure 1** – Graph of the total consumption in Reais comparing the measured consumption and consumption after the EPIAs carried out by the ESCO energy management program.

Thus, to find the energy savings and the variation caused by the measurement uncertainty arising from the application of the energy management program carried out by ESCO considering a 95% confidence, which results in a total savings of R$ 54,123.89 accumulated in 7 months of operation of ESCO. These savings represent 7.60% of average in comparison to the monthly bills, with a relative precision of 17.6%. For this level of confidence, the absolute precision is R$ 9,532.64, meaning that the savings can vary between R$ 44,591.26 and R$ 63,656.53.

5. Conclusion
In this article, it was proved that programs of electric energy management can generate savings, measuring some actions of energy efficiency in management made with a relative precision of 17.6%.
The ISO 50001, 50002, 50004, 50006, 50015, PIMVP and GUM standards were used successfully to obtain the final savings.

It is necessary to deepen studies on this field, because energy efficiency and energy conservation gain more and more importance nowadays.

Instead of using IPMVP C option was used in this project, because of the amount of energy other IPMVP options should be used, which would give more detailed metering. The next step of this work will be usage of others metering options to improving the effectiveness of the energy savings and the proposed mathematical model.

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