

# Ten systemic steps for sustainable energy savings in small and medium enterprises

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**Abstract.** Energy savings are a priority in the different industrial sectors including Small and Medium Enterprises (SMEs). They have a conceptual perception of energy savings by replacing their service and production technologies with more efficient one. However, this technological change requires large-scale investment. There is another approach that can be used to reduce energy costs that has less impact on company production costs and does not require investments in technology. This approach considers planning and control procedures, which are considered in the present study. This study proposes a new method consisting of 10 systematic steps to achieve energy savings in SMEs. This method initially evaluates when, how, and where the energy is used, then identifies opportunities to achieve sustainable energy savings. The method involves various activities including an assessment of energy efficiency based on final energy consumption, adjusting production plans with low energy consumption and costs, and monitoring the energy budget. Application of this methodology in SMEs can save energy around 5 – 20% over a period of 1 to 3 y with some very low payback periods of less than a year. Operational controls implementation in Significant Energy Uses (SEU) can save energy around 2 – 5% of the consumption, without requiring investment in technology.

## 1. Introduction

Energy efficiency is an important strategy [1] to generate significant savings in energy consumption in government, industry, and household levels. This strategy contributes to the mitigation of greenhouse gas emissions through the efficient use of energy in each entity [2]. Energy efficiency can be seen as a tool that not only evaluates the energy savings potential [3], but also promotes pollution reduction without requiring the use of specific types of energy for a specific level of technology [4]. There are various ways to approach energy savings programs but the majority of SMEs [5] believe that their implementation requires an initial investment to expand or sustain their production. This perspective might be true if energy savings are seen as a modernization of service and production [6] technologies or their replacement with more efficient one [7]. However, there is another approach that can be used to reduce energy costs that have less impact on company production costs and does not require investments in technology [8]. It considers planning and control procedures [9]. This approach has similar results to technological change, but its implementation takes a longer time as it needs to recover low and medium energy savings potential and maintain them for a certain period of time, in which the savings obtained over time becomes an important capital for the company [10]. The implementation of this method has the advantage of being able to change the operational culture of an organization [11] that can be transferred to other resource savings, such as water, raw materials, and by-products [12].



## 2. Methodology

### 2.1. Energy management systems

This section describes the actions that must be taken into account to achieve energy savings in SMEs, considering the relevant step by step operations to comply with the proposed actions.

### 2.2. Ten steps to energy savings in SMEs

*2.2.1. Step 1: Evaluate when, how, and where to use energy.* The general energy balance of the company from primary to final use should be defined, where the monthly energy costs for production will be identified. Then, the company's SEU is identified using Pareto diagrams based on energy types and estimated consumption of processes and equipment. This process allows the identification of which equipment and processes consume the most energy and tries to reach 20 % of those that consume nearly 80 % of energy.

*2.2.2. Step 2: Analysis of the opportunities offered.* To take advantage of the opportunities offered by the legislation that promotes the rational use of energy, in order to consider them as a regulatory basis in the process of energy saving in companies. There are several energy regulations that promote the rational use of energy and environmental conservation in Colombia including [13]

*2.2.3. Step 3: Evaluate the energy efficiency.* Companies should evaluate their energy performance, which is usually done with monthly comparison of absolute energy consumption, monthly comparison of energy costs, and monthly comparison of energy consumption rates (energy/production unit). However, none of these forms evaluates the energy efficiency of the process with respect to the use of the energy used, i.e. it is not known whether the process is energy efficient or not. This is due to the influence of load factors on energy consumption, which shows that the total energy consumption of a company, process, or equipment consists of two types of consumption: fixed and variable. Fixed is the energy used that does not depend on the quantity produced, whereas variable is the energy used that depends on the performed production.

*2.2.4. Step 4: Plan production at a low consumption rate.* In daily production practice, when monthly production increases, the rate of consumption (amount of energy/unit produced) indicates that the rate of consumption is dependent on variable factors related to production which may be variable or constant, proportionally impacted on consumption.

*2.2.5. Step 5: Identify an appropriate energy budget.* Proper planning of the detailed amount of the final use of energy should be made, which allows to evaluate and monitor system performance.

*2.2.6. Step 6: Effectively control the energy budget.* The monitoring of the company's energy budget is strictly focused on monthly consumption, not taking into account aspects that involve energy efficiency, such as baseline consumption within the same budget of expenses and investment in the company. In order to avoid the exclusion of important aspects, it is proposed to prepare energy budgets on a consumption baseline basis, where it is possible to identify how much the actual energy consumption changes from what is planned, taking into account the changes in production, evaluating the actions involved in energy use efficiency.

*2.2.7. Step 7: Identify sustainable cost reduction goals.* The reduction of energy consumption in companies is usually done with technological changes to improve the energy efficiency of equipment or production lines, reduce leakage or improve insulation in expected outcomes of a particular program or service, or refine the control system, where the impact is planned.

**2.2.8. Step 8: Effectively monitor compliance with SEU objectives.** This step is done not only by measuring and recording the actual consumption value at the end of the period and comparing it with the predetermined consumption, but also by monitoring the energy yield per hour or per day, so that at the end of the month or period the compliance with the silver targets is reported at the beginning of the measurement.

**2.2.9. Step 9: Identify and control the variables that affect consumption.** The variables that affect the energy consumption of a company are processes and equipment. The application of the energy efficiency trend graph method in significant uses, with an appropriate period (per hour or day) of observation and recording of operational changes, maintenance or events, makes it possible to establish the operational variables which can be expressed in tables that allow the information to be condensed in a clear way.

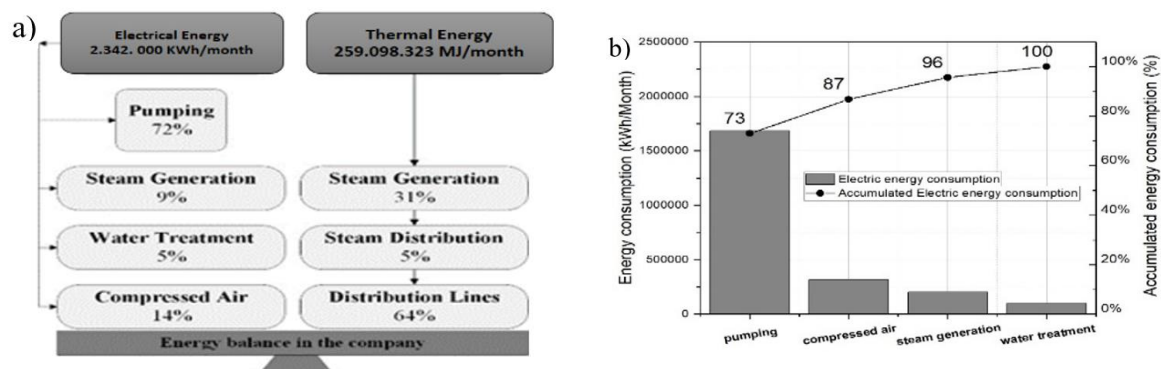
**2.2.10. Step 10: Identify technological advancements projects.** The identification of technological advancement projects is conducted based on EMUs energy diagnosis that is generally performed by specialized personnel.

### 3. Results

#### 3.1. Implementation results of the ten steps

The implementation results of the proposed steps obtained from fifteen SMEs, the energy and production data were collected from the historical operations data, with an hourly frequency over a period of one year of operation, with the Scada system and supervision.

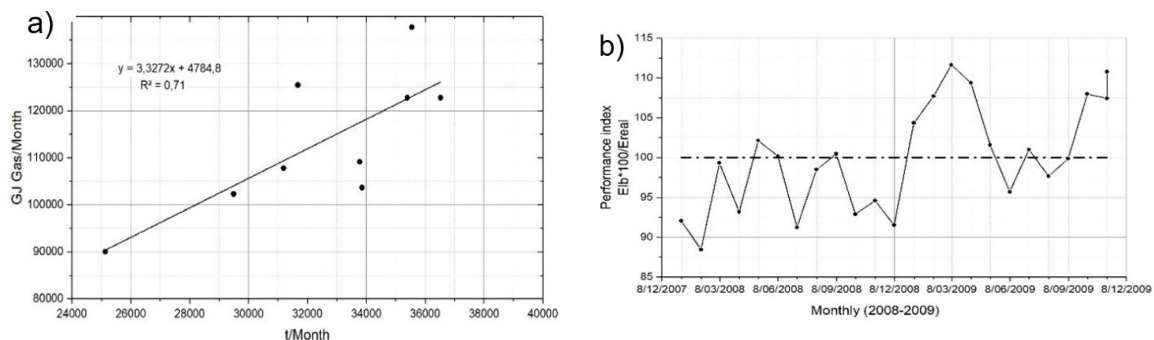
**3.1.1. Step 1: Evaluate when, how, and where to use energy.** A common misconception in making such balances in companies is that the end use of energy is misallocated. Figure 1(a) shows that the consumption allocated to each end-use area is the energy expended, not the energy that enters the area. For example, the steam generators in the diagram below supplied 100 % of thermal energy, but only 31 % is spent to overcome the losses, the rest is transformed into useful energy from the steam that passes into the steam distribution system. It receives 69 % of thermal energy, but only 5 % is lost through heat transfer to the medium, the rest go to the next process. In this process, where the energy used and where the most significant potential for reducing its used can be identified. Figure 1(b) shows that in two processes that represent 33.3 % of the total, 87 % of the energy consumption is concentrated. This would be the SEU and variation in consumption due to changes in these two processes.



**Figure 1.** Energy evaluation tools: (a) Energy balance sheet (b) Pareto diagram of energy use.

**3.1.2. Step 2: Take advantage of the opportunities offered by legislation and the environment.** It was verified that the energy bill: consumption sector; charges; type of user; loss factor; correction values of the measurement equipment are duly read and invoiced as established by the regulations.

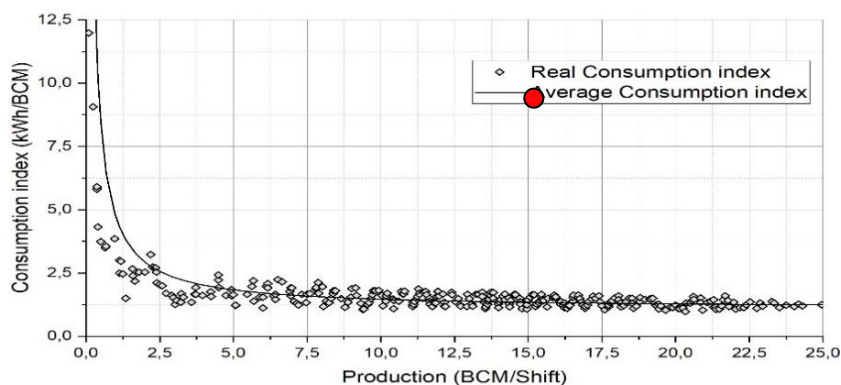
**3.1.3. Step 3: Evaluate the energy efficiency.** Process or equipment has an installed production capacity and it does not always 100% work. The fixed energy consumption practically independent on the use of installed capacity in most processes and equipment, while variable energy depends on it. The appropriate way to measure energy efficiency is not by comparing the results of one month's consumption with the other months but comparing the results of one month's consumption with what should have been consumed for the actual units of production in that period, as shown in Figures 2(a) and Figure 2(b). This can only be done if there is a baseline of consumption that allows to know how much it should be consumed in that month. To properly evaluate the efficiency with energy consumption, it is necessary to prepare the baseline of consumption and determine the energy performance indicator month by month.



**Figure 2.** Energy indicator: (a) Energy consumption baseline, (b) Monthly energy performance index performance graph.

**3.1.4. Step 4: Plan production with low consumption rate.** For example, a tailings removal process in a mine, working with productions higher than 12500 CM/shift guarantees rates of 1KWh/CM, (Cubic Meter of Material- CM) below which it is possible to reach up to 12.5 times more. To achieve successful results, the following was done.

- Graph Consumption Index vs. P (production).
- Identify the minimum monthly production, where the Consumption Index is low and almost constant.
- Identify the minimum monthly output, where the IC is almost constant.
- Determine the appropriate hourly production rate.
- Plan the processes, as shown in Figure 3.



**Figure 3.** Behavior of energy consumption index of a sterile removal process in electric shovels.

**3.1.5. Step 5: Identify an appropriate energy budget.** For identifying the energy budget, the companies should perform several processes.

- Calculate the average value of the consumption index for the year before the targeted year.

- Determine the planned value of annual production for the targeted year.
- Calculate the planned consumption value for the targeted year.
- Estimate the energy tariff for the targeted year by considering its indexation.
- Convert the budgeted energy consumption to local currency.

3.1.6. Step 6: Effectively monitor the energy budget. The companies for any month presented a production value P and its corresponding value of the budgeted energy  $E_p$ , in most of the fifteen companies the  $E_p$ , did not coincide, therefore, with the application of establishing the mathematical relation of the baseline from which the energy consumption budget determine how much of the variation in the real consumption with respect to the budgeted one was due to differences in the real production with respect to the budgeted one and the number of changes in the efficiency, to variations in the real consumption.

3.1.7. Step 7: Identify sustainable cost reduction goals. The identification goals for this concept can be known by applying the process described below and it can be visualized as in Figure 4(a).

- Develop the company's consumption baseline, process, or equipment, where the goal would be set.
- Calculate the baseline using the baseline correlation graph and its trend line.
- Subtract the fixed consumption value of the baseline from the fixed consumption value of the target line.

3.1.8. Step 8: Effectively monitor the achievement of SEU targets. his step consisted of several activities that allowed the monitoring of both the behavior of energy indicators such as production, consumption index as the achievement of objectives and the identification of the cause that may affect compliance with the same some of the graphs that allowed to assess the results shown in Figure 4(b). These activities are mentioned as follows.

- Create daily or hourly baseline of consumption for the base period.
- Record the current period of the energy consumption (Ereal) and associated production (Preal).
- Determine the consumption that is existed in the base period.
- Calculate the deviation from the actual use compared to the waste of the base line.
- Find the accumulative sum of the variances for each day or hour, from day 1 to day 30 in a month, or from hour 1 to total monthly working hours.
- Create a trend graph (the value of the accumulative sum of the variances against each day or hour in a month).

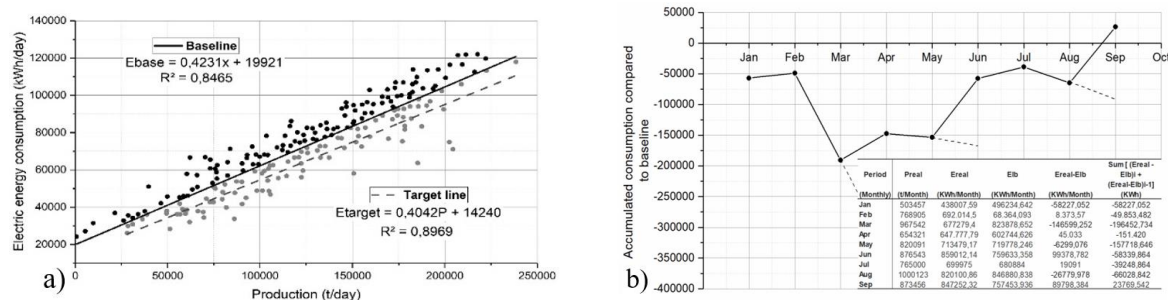


Figure 4. Energy indicator: (a) Baseline and target line for energy consumption (b) Data logging for energy performance charting with monthly energy performance tracking chart.

3.1.9. Step 9: Identify and control variables that affect consumption. Variables that affect consumption in production lines or processes are lost time, product changeover times, equipment start up times, equipment downtime, empty working, low load factors, number of rejects, and use of less efficient equipment. In that energy service equipment, which is SEU, variables that affect consumption was

related to the same variables that cause energy inefficiency. For example, the working regimes outside their optimum operating zone in pumps, the high air suction temperature in compressors, air leakage in the system, the type of regulation of the compressor working regime, the purging government in boilers, and the temperature of combustion gases. Table 1 shows the operational procedure for a steam generator.

**Table 1.** Record format for the operational control of variables that affect energy consumption in significant energy usage.

Operational control register steam generator	Fuel type	Boiler number	Month	Week	Working pressure
Daily check-up.	GN	2	January.	2	150psig
Activity/operation.	Standard Parameter.	Shifts	Criteria.	Possible cause of deviation	Possible action.
Measurement of gas and steam temperatures at high temperature from steam temperature.	50°C	1 2 3	45 – 60°C	Dirt from boiler pipes; excess combustion air.	Combustion adjustment; boiler tube cleaning.
Analysis of total solids in boiler interior water	3500ppm	1 2 3	2500 – 3500ppm	Inadequate purge rate.	Adjustable purge rate.
Analysis of the composition of CO in exhaust gases.	< 150ppm	1 2 3	0 – 150ppm	Inadequate excess air.	Excess air adjustment.
Working pressure PSIG.	150psig	1 2 3	148 – 151psig	Steam demand changes.	Modulating pressure regulation.

*3.1.10. Step 10: Identify technological advancements projects.* The primary source of technological advance starts from the revision and adjustment of the power factor of sizeable electrical equipment consumers, in addition to the changes of flow regulation systems by frequency variations, the revision of waste heat recovery systems, such as recuperates, absorption chillers, heat exchangers, and flash tanks. Similar conditions are applied in the on-site generation processes, such as self-generation, cogeneration, and trigeneration.

#### 4. Conclusions

The implementation of the ten steps to increase energy performance in SMEs can produce energy savings about 5-20 % over a period of 1 to 3 years with a very low payback period of less than a year. The proposed method only needs the operational controls implementation in SEU, which can save energy around 2-5 % of the consumption, without requiring investment in technology. Successful implementation of these steps should be supported by the training of the involved personnel to effectively implement the method. It is important to note that the more rigid the application process of the ten steps proposed, the greater the effectiveness of achieving energy savings, with a proportional impact on the reduction of energy costs. However, this requires investment in energy metering and recording equipment for each SEU. The proposed method can be easily applied to companies where their equipment allows the measurement of energy consumption, in the same way companies where their equipment is obsolete, or it is not possible to quantify its consumption, with good operational practices, energy savings will be achieved.

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