doi:10.21311/001.39.7.15

Energy Efficiency and Decision Areas: A Cognitive Study of This Relationship

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Abstract: The energy is a vital factor for the operation of industries, however, the integration of this variable in productive performance measurement systems is found in a limited way in the literature and in practice. However, the impact entailed in energy consumption before some decisions in specific areas, is still unknown in its entirety, therefore, the main objective of the research was to perform a cognitive analysis that relates the decision areas with indicators, procedures and strategies proposed in the literature, for energy efficiency in production processes. Thus, an extensive review of the literature was carried out, structured by a systematic review, from which the texts were selected for analysis of the relationship between energy efficiency and decision areas. It was adopted the decision areas proposed by Skinner (1969) and by Hayes and Wheelwright (1985) and it was possible to extract the existence of the relationship between energy efficiency and all areas, however, some relationship apparently stronger than others.

Key words: Energy Efficiency; Decision Areas; Manufacturing.

1. INTRODUCTION

The efficient use of energy has been featured on the world stage, not only for raised consumption of energy, but also for the economic effect that the lack of an energy program may cause. According to Patterson (1996), the energy efficiency (EE), in the industrial sector, can be measured from the amount of energy required by the process and the amount of products it generates. To Espinosa and Salinas (2008) the industries aims to transform raw material into manufacture by the energy aggregation; in addition, the demand around EE has also grown due to the increased concern for environmental impacts caused by energy use. Some studies show energy security in an indirect contribution to reducing energy use, consequently, the energy efficiency (Takano, 2008).

According to Moskalenko et al (2012), an efficient operation can save energy without changing the structure and parameters of the power supply system, so that by means of a detailed investigation, it is possible to identify the devices that are not functioning optimally. The measurement energy systems in a production environment can direct the efforts of a decision-making to the exact point of the problem and can contribute to the business strategy, benefiting the production costs as well as the organization of work.

The performance measurement systems, in turn, are composed by indicators of production performance, organizational, economic, among others, and has been a valuable tool for analyzing the efficiency and effectiveness of industrial operations. However, in most cases, the production indicators do not include the variable energy in their actions. These indicators can be used, for example, to measure the influence that operational changes can have on energy demand or in all activities this resource. These indicators may be an indicative of how energy is related to the economic and technological parameters (Patlizianaset al., 2007).

The business strategy commonly aligns with the decision areas of the company, and according to Choudhari (2012), the skills of a production system, depends on some individual decisions, characterized by decision areas of the system. According to Skinner (1969), the decision areas are defined in Plant and Equipment, Production Planning Control, Personnel, Product Engineering and Organization Management. To Hayes and Wheelwright (1985) the decision areas can be allocated into two groups, the structural group, which has the following areas: Capacity, Facilities, Technology and Vertical Integration; and the Infrastructural group, which has the following decision areas: Workforce, Organization, Quality and Planning Production Control.

In this scenario of deficiency integration between various decision areas of a production system and energy efficiency, this study aims to analyze the cognitively literature presented in energy efficiency in production environments and its relation to decision areas, thus promoting a collaborative vision of the strategic decisions and their influences on the energy use in a production system. Therefore, it was chosen to work with the systematic review of the literature and perform cognitive analysis from the perspective of procedures and strategies adopted for management of energy consumption and energy performance indicators.

2. METHODOLOGY

The study began with a systematic literature search, directed by strings search set from the research questions, which were selected texts relevant to the theme of this study for further critical reading. Thus, it is a
basic nature research, with qualitative approach and exploratory objectives. In Figure 1, it is possible to observe the steps of the systematic literature review.

| A. Definition of research question |
|-----------------------------------|
| RQ1. What are the energy performance indicators used in production environments? RQ2. How the energy performance indicators relate to decision areas in a company? RQ3. Is there a reference model adopted for the energy performance management in production environments? |

| B. Identification of databases relevant to the theme of research |
|---------------------------------------------------------------|
| Science Direct, Emerald, Springer, IEEE Xplorer, ISI Web of Knowledge, Scopus, Cambridge. |

| C. Definition of keywords |
|--------------------------|
| Search Strings: “strategy AND energy AND efficiency”; “strategy AND energy AND operations”; “strategy AND energy AND management”; “productivity AND management AND energy” e “productivity AND indicators AND energy” |

| D. Establishment of criteria for inclusion and exclusion of papers in the portfolio |
|-----------------------------------------------------------------------------------|
| Inclusion criteria: studies describing indicators, systems, practices and procedures for energy performance and production performance, and studies correlating the energy performance with decision areas. Exclusion criteria: previous publications in 1994 that do not have digital version, not scientific, repeated and not reaching the goal of the research. |

| E. Search on databases with a preliminary reading |
|--------------------------------------------------|
| The preliminary reading was structured and focused on the study objectives, seeking to characterize the study material through their contributions and concepts used. |

| F. Application criteria for material selection |
|-----------------------------------------------|
| In applying the criteria for selection of material, items that did not fit the criteria defined in step D were excluded. |

| G. Critical analysis of the material and application of the reflective reading criteria |
|--------------------------------------------------------------------------------------|
| CR1. The paper describes energy performance indicators in production environments? | CR2. The work uses a reference model? | CR3. The work develops or adopts a procedure for the development of energy performance indicators? | CR4. The paper reports recommendations on the use of performance indicators in production environments? | CR5. The work related indicators of production performance with the decision areas of the company? |

| H. Synthesis of information from the selected material |
|-------------------------------------------------------|
| Considering the content analysis methodology, the selected material was categorized into: articles related to sustainability and those related to management operations. The focus of study were the articles of operations management. |

**Figure 1.** Steps of the systematic literature review, adapted from Sampaio and Mancini (2007).

Using the methodology proposed, it were selected, as relevant to this research, 186 scientific papers published between years from 1994 to 2015 with significant growth from 2007. According to bibliometric analysis, only 20 articles represent 70,2% of all citations of entire portfolio selected and is possible to highlight countries with greater productivity, such as: USA, China, Germany, United Kingdom, Sweden, Spain, Netherlands, Italy, Malaysia, South Africa, Australia, France, Ireland, Greece, India and Switzerland, totaling 78,6% of publications. As the journals that had the highest number of relevant publications to the theme of this study, the main ones are Energy Efficiency, Energy Policy, Applied Energy, and International Journal of Energy Sector Management. According to Pareto curve, only 21 journals totaling 70,8% of the publications.

According to the categorization defined, 72% of the articles are in the category "Operations Management (OM)", which is the category focus of study, while 28% complete the category "Sustainability (SU)". Of the
articles in the "OM" category: 35.3% are related to exposure strategies for energy management in manufacturing; 33.8% with the practices and recommendations for energy efficiency and 30.8% had used performance indicators for energy in manufacturing environments.

In the next sections, the analysis of portfolio texts will be presented, in order to answer the three research questions defined in the methodology and list the procedures, practices and energy performance indicators with the decision areas defined by literature, through a cognitive analysis. To Varela and Maturana (1992), “this situation, implicitly or explicitly the organization of an object is recognized when indicated or distinguish, it is universal as something done constantly: a basic cognitive act.” Thus, cognitive analysis was performed using the knowledge and experience of the authors, considering the decision areas, from the indicators exposed, practices and procedures for energy management and the characteristics of the decision areas outlined by Skinner (1969) and by Hayes and Wheelwright (1985; 1988), summarized in Appendix A.

3. STRATEGIES AND PROCEDURES FOR THE ENERGY MANAGEMENT SYSTEM (EMS) AND DECISION AREAS

According to Wheelwright and Hayes (1985), the following decision areas are capacity, facilities, technology and vertical integration, workforce, organization, quality, planning and production control. To Skinner (1996), the decision areas can be classified into plant and equipment, planning and production control, human resources, product engineering, organization and management. To Corrêa and Corrêa (2009) the decision areas can be divided into product design and service, process and technology, facilities, capacity / demand, workforce and project work, quality, organization, queues and flows, systems planning, scheduling and production control; information systems; supply chains; customer relationship management; performance measures and enhancement systems. Thus, as defined in section 2, it was chosen to work with areas related to both authors: installations (INST), technology (TEC), human resources (HR), quality (QLD), planning production control (PPC), organization and management (OM), logistics (LOG) and product engineering (EP).

Some of the previously described decision areas can be related to the management strategies outlined by Kulkarni and Katti (2010) to promote improvements in energy efficiency, which can cite the energy audit; energy costs; cutout refill; use of materials; maintenance operation; lighting; alternative energy resources; human resources; modernization and energy management.

For the evaluation of energy use in the audit process, which could be related to the area of organization (OM), first, working with the phase of preliminary studies, for only then evaluate the detailed project execution and facilities. The evaluation of strategy cost is based on energy bills that usually feature the monthly energy consumption. The third strategy consists of the analysis of the refill behavior related to the area of systems and technology; the fourth strategy is to maximize the use of materials and to encourage recycling; the fifth strategy is to optimize the use of components and the sixth strategy relates to lighting the local. The studies of alternative energy sources are presented in the seventh strategy. Training and awareness are also aligned with the organization area and the energy utilization is related to the improvement that can be obtained in the eighth strategy; and finally the last two strategies dealing with upgrading equipment (plant area and technology) and the establishment of procedures and methods for the energy management (OM) (Kulkarni and Katti, 2010).

For Dusi and Schultz (2012), an energy management program must have the participation of all representatives of the company from the board, such as finance, production, maintenance, quality, engineering and others. It is extremely important to engage all employees in all stages of the process. Employees are not only responsible for achieving the program goals, but also acting as program facilitators, promoting communication of goals with their respective departments. To Moreno and Medina (2011) the price of energy is influenced by some factors, as economic, political, financial, risk and regulatory conditions, and these factors must receive attention as the strategies areas. The monitoring of energy will know where it is consumed, will also enable the monitoring costs and calculate the amount of energy per each stage of production (KWh/ton). The audit is a key process of the energy management program, as it allows access to action plans, goals achieved and progress of the program. It is suggested that the auditing system assess the following questions: historical data of energy consumption per machine; study of maintenance reports to determine the best and worst facilities; calculation of savings and rate of return and; study of current electrical distribution system. As for goals, it is suggested that they be specific, measurable, attainable, relevant and made in time (Dusi and Schultz, 2012). A generalized cognitive analysis, it can be said that the action strategies on energy efficiency proposed by Dusi and Schultz (2012) are related to the organizational area, however, for the generation of positive results, the authors emphasize the need for participation and integration of the various decision areas.

The ISO 50001: 2011 defines an energy management system as the combination of elements in an organization, with the strategic objectives on energy policy and has the following objectives:

- Representing energy flows transparently;
- Constantly improve energy efficiency through continuous monitoring of energy flow;
• Identify potential energy savings for the accuracy of data;
• Cut energy costs and CO2 emissions;
• Create a competitive advantage through optimized process guidance for energy consumption;
• Awareness of employees towards the energy management system and its objectives;
• Verification of legal greetings;
• Provide a basis for tax reduction.

Accordingly, the ISO 50001:2011 proposed actions are the following intrinsic decision areas: organization and management, technology, installations and planning production control.

Moskalenko et al (2012) believe the strategy of an EMS consists of a few basic elements:

a) Monitoring, where energy consumption data are collected and analyzed in order to identify potential energy savings;

b) Automation, automatic process control can provide continuous improvement and detect changes in energy demand and supply energy;

c) Online control, which is the analysis and continuous monitoring of energy,

d) Maintenance and control in order to avoid non programmed stop and;

e) Energy meters.

The concept of energy management is the continuous data collection, evaluation measures and visualization of the results. Therefore, EMS need equipment, communication tools, control systems and customers. The decision areas highlighted in the actions proposed by Moskalenko et al (2012) are technology and planning production control, since it is stressed the need for monitoring and measuring energy consumption, as well as planning the demand.

In study, the authors Rudberg et al. (2013) attempted to answer the following questions: a) What issues are important to consider for the establishment of a strategic perspective on the energy system in a company? b) What issues are important to consider getting strategic attention to the energy system in a company? iii. What issues are important to consider obtaining strategic attention on research possibilities to find efficient alternatives to the energy system in a company?

In the first question answer, three points were detached; the first is the need for policy continuity with energy issues, so that the investments can be reduced. Second, it was possible to realize that even the energy issue is not the core business, it can be the core of the business, since the cost of energy is much of the added value. And finally establish an organization containing an energy management that is responsible for energy management of the company, and may incorporate the possibility of integrating energy planning for energy saving initiatives at the corporate level (Rudberget al, 2013). Such a response can be directed by the strategic decisions of the organization and management area, since it is the definition of EE policies.

Answering the second question it were raised four important points to obtaining strategic attention to the company's energy system. The first was the need for centralization of energy planning and accountability of energy efficiency initiatives; potential identification of energy saving and focus on investments with better energy solutions, considering the environmental impacts in decision-making; focus on efficiency and effectiveness of the energy system (using load management methods, analysis and energy waste disposal). And finally, work with process innovations with regard to the quality of energy and its alternative costs (Rudberget al, 2013). Cognitive analysis can be related to the response of the second question with strategic decisions of technology on product development.

Finally, the last issue addressed by the authors, with regard to research alternatives to energy system efficiency. It was also detached three key strategic points: the location of the companies can influence profitability; the use or reuse possibilities can add the production process in order to transform surplus energy alternative economy, or electricity or district heating, among others. And furthermore, government support that can promote the competitiveness of sustainable energy (Rudberget al, 2013), giving thus greater emphasis to the areas of installations, technology and planning production control.

Some studies show that companies have difficulties in following steps, such as the evaluation of the initial situation due to lack of data, not focus on major energy consumer and derive improvement measures for the same, and implement continuous improvement processes by a lack of interaction of employees. Overall, to Dorr et al (2013) energy management systems should contain: an energy policy with operational and strategic goals; an initial energy legal position; organizational structure, processes and responsibilities; training systems, documentation, communication and reporting; procedure for continuous process improvement and planning system with the planning processes defined.

Based on ISO 50001:2011, Dorr et al (2013) propose the components of an energy management system and the use of a framework that defines the system settings, organization, structure and processes. It is considered the place where the power system must be allocated and act in global planning. The operating technical system is the system for actions, measures and achievements, including the observation of objects, such as products, processes and services. Between the framework and the operating system, operates a control system where detailed planning is carried to the various levels and their requirements are broken down into...
operational goals. The authors seek to relate the energy efficiency project with the necessary extensions in the technical control system, with the goal of creating a technical basis for a continuous improvement of energy efficiency process level (Dorr et al, 2013).

As a success factor it may suggest the use of a catalog of measures based on the process that allows reducing energy consumption, acting as drivers in making process-level decision. It is about the creation of a document in process level, with possible general and detailed measures, such as cost savings, amortization, savings potential, process and quality risks, among others; which will operate as an integrated database of information technology technical control system (Dorr et al, 2013).

Analyzing the energy efficiency system, the framework and the EE project proposed by Dorr et al (2013), which also has reference to ISO 50001:2011, based on a PDCA model, it appears that for this system causing efficient results, decisions happen strategically in the areas of organization and management, installations and technology.

Considering the historical development of standards aimed at the energy consumption and focusing on the ISO 50001:2011, O’Driscoll et al (2013) observed that an energy management system addresses energy efficiency, conservation and performance management, highlighting how main components: strategic plan; management team; identification of energy projects; energy manual and energy performance indicators. In proposals by O’Driscoll et al (2013), it is clearly observed the priorities established in the organization and management area, which is also expected to be treated in a work of analysis of strategies and procedures for energy management in environments industrial.

Duflou et al (2012) propose a strategic model to increase energy efficiency in manufacturing industries that is divided into three initial stages, which lead to two. The first stage is focused on supply chain, where you have to identify machinery, chain links, material flow, takt time and the available production programs. The second stage refers to an energy analysis of production, highlighting the inputs and outputs and the average energy consumption. In the third stage, there is the energy technical analysis, the identification of relevant equipment, analysis of inputs and outputs and the average energy consumption. These three steps leading to a fourth step, the load profile and energy cost, where work with consumption, cost analysis detailing the composition and contract specifications. Finally, the last stage has an integrated simulation and evaluation of the production system through process modeling, data integration measures and contract specifications and technical considerations. This is a strategic model, focused on organizational and management area, technology, logistics and planning production control.

According to Abdelaziz et al. (2011), to achieve energy efficiency in the industrial sector, it is necessary to address three strategic issues: energy savings achieved through management for technology and energy policies, intrinsically already addressing the areas of organization and management, as well as technology. Thus, a typical management program must have definition of energy policies, audits, educational plans, reports and strategic plans. In the audit process, it first establishes a team, then the objectives and goals, in sequence gather historical data, the audit is carried out, the results should be in a report from which priority should be given to implementation, establish measures and verify the performance to maintain the measures. This process can ensure control of industrial energy consumption (Abdelaziz et al., 2011).

Regarding sustainable development, the search for energy efficiency has been a key issue and has directed great efforts in recent decades to the energy consumption measurements, understanding the impact on energy consumption and around the effective policy design of energy efficiency. Lombard et al. (2013) suggest that the energy is used in sum, around three bases reasons activity, structure and strength, so that the "activity" means a phenomenon that generates an energy demand. The term "structure" is used to explain the relationship between different activities and the term "intensity" refers to the measure of the amount of energy to be delivered to a unit for service or production of consumer goods. Lombard et al. (2013) also propose a sequence of actions that are intended to assist and reduce the problems encountered during the development of energy performance indicators such as the quality settings you need to identify what are the quality requirements for each company, so specific, for example, speed of service, safety, comfort, and others. The level of aggregation, hold up work with the pyramid efficiency. In the third step you must select the magnitude of the energy measurement and finally, selecting the measure of greatness (Lombard et al, 2013).

Energy efficiency, for Palm and Thollander (2010) has some barriers especially in three perspectives: economic, organizational and behavioral. In the economic dimension are related imperfect information, asymmetric, hidden costs and risks. As for the organizational perspective, we can highlight the lack of managers for energy, negligence led to organizational culture and environmental issues. Finally, the behavioral dimension can highlight the inability to process information, the format of the information, confidence and inertia.

Like Palm and Thollander (2010), Abdelaziz et al. (2011) also attribute some dimensions to energy efficiency, such as legal dimension, environmental, technological, social-economic, and financial dimension. This division into dimensions implies that energy efficiency programs, training and management are developed on these perspectives, to raise awareness and control of energy consumption and understanding of their impacts (Abdelaziz et al, 2011). On the same way, to Bunse et al. (2011), the use of energy can also be divided into
dimensions for better understanding, the social, economic and environmental dimensions. Based on this division it is possible to establish dimensions in the development of energy management system in industrial environments.

Jaffe and Stavins (1994) propose a graphical summary for analysis of gaps in energy efficiency by aligning energy efficiency qualitatively (vertical axis) with the business level (horizontal axis). It finds that between the elimination of market failures through efficient energy technologies, and to obtain benefits from these disposal, there is an extensive field of study that involves economic potential technologies, fault in the energy market, barriers in the energy market and its effects and the environmental conditions for energy efficiency.

The framework presented by Fenerich et al (2013) establishes the connection between the strategy of the functional areas of a company (marketing, production, finance and human resources) as well as the decision areas inserted in the production strategy. These decision areas (product development, process engineering, maintenance, facilities and quality) are directly linked to the company's energy policy, which derives a strategic plan for energy and its operations. It is based on the energy management system model proposed by ISO 50001:2011 along dimensions of performance that can be observed in the BSC model by Kaplan and Norton (1996) and the sustainable perspectives from Neves and Leal (2010). It can be seen in Figure 2.

Figure 1. Framework by Fenerich et al (2013).

According to Fenerich et al (2013) to monitor this system, it is proposed five dimensions. (1) Social perspective, which is aligned with the production strategy and the strategy of human resources. (2) Economic perspective, which is the dimension that is aligned with the following decision areas: product development, process engineering, maintenance and facilities. (3) Environmental perspective, it is a way to analyze the environmental impact of the process and is aligned with the area of quality and process engineering. (4) Perspective innovation / learning is, basically, associated to all decision areas. (5) Internal business perspective is also aligned with all decision areas and should measure the approach of the results obtained through the activities outlined in production strategy, the planned targets.

3.1 Summary of the Cognitive Analysis of the Strategies and Procedures for Energy Management Systems and Decision Areas

Through cognitive analysis of the topic 3, it can be exposed in a simple and clear in (Figure 3), which decision areas are intrinsically related to energy management models proposed for each of the studied authors.
It can be seen in Figure 3, that implicitly or directly, all decision areas appear detached in studies. However, the logistics and quality area are the least noted in the relevant strategies and procedures study. Making a reflection on the proposed models, means the need for alignment mainly to the organization area and management, since this unit of study, these are the strategies and procedures for energy management within the category of operations, according to the methodology used to develop the study. As the areas of technology and installations, which generally involve long-term decisions and high cost, or strategic decisions.

Some models also highlights the need to develop products that are more efficient as energy consumption, also referring to a strategic decision and long-term horizon. Already the mention of the planning production control area, in most cases is related to the planning and control of energy consumption of the production area, seeking reuse of resources, minimizing rework and wasted energy. Aligned with this same analysis, there is the logistics area aimed at integrating the production chain, mapping all material and energy flows. However, it is possible to demonstrate the absence of quality areas and human resources in the proposed models for energy management.

4. INDICATORS OF ENERGY PERFORMANCE AND DECISION AREAS

The indicators are used widely in different fields as tools that provide information on measures of change or process phenomenon. The energy indicators has become a key part in the development of energy policy, since its use allows for a trend analysis with historical data, comparative analysis and performance monitoring of past and present policy. In general, they provide information to assess the consumption and energy changes (Lombardini et al., 2013).

To Patterson (1996), indicators that can monitor changes in energy efficiency can be divided into four categories: the thermodynamic, physical-thermodynamic, economic-thermodynamic and economic, involving the enthalpy variables, entropy, Gibbs free energy, temperature, energy, and outputs in monetary unit terms. However, these same indicators were still presenting some limitations, for example, measures the energy efficiency of the general process. In a way, the indicators proposed by Patterson (1996) relate the installations and technology areas when using temperature measurements, Gibbs energy, entropy and output in financial terms, since the change of the structure and type of technology may involve changes in these variables.

Kulkarni and Katti (2010) propose the use of two general indicators, Plant Performance Factor and the Energy Consumed that is the use of energy efficient in general, somewhat stratified on procedures or areas; which also form cognitive believed to be associated with installations and technology areas.

According to Neves and Leal (2010), an energy system that reduces the effects caused to the environment, which increases the opportunities for economic and social development, with a long-term perspective it is the basis of a concept of sustainable energy. In this context, three dimensions can be developed: environmental, economic and social; and proposes the distribution of various indicators in the production chain, such as the use of final energy by sector, the local rate of renewable energy production for local consumption of energy and electricity, the emission of pollutants by transport activities, among others.

The observation that is possible to make in the indicators proposed by Neves and Leal (2010) is that they address almost all decision areas detached in this study, since they present indicators for the entire chain.
been the policy indicators related to the field of management and organization and other indicators present the production chain, distributed among the areas of logistics, installations, technology, human resources and planning, production control.

Whereas a process has at least seven factors that can vary per product unit energy consumption, namely: equipment, methods of operation, energy category, raw material, management system, energy saving activity and use of production capacity, Wu et al (2007) developed an energy efficiency indicator system in process level, considering a mathematical function with seven independent variables. The model is able to distinguish the difference in energy between energy related to the activities and use of process equipment, allowing qualitative and quantitative analysis and its energy saving values or excessive use due to energy variation in the process. Through the analysis of the variables proposed by Wu et al. (2007), is possible to extract the relationship with management and organization, facilities, technology, quality, human resources and planning production control areas.

According to Duflou et al. (2012), the energy input is a product of a process, water recycle, and emission of gases, solids, liquids and heat. Indicating that these variables can be used for defining energy efficiency indicators of the process, as highlighted in section 3, the proposed strategies and procedures for managing energy efficiency.

The objectives of energy policy for Patlitzianas et al. (2008) can be divided into three groups; the first is safety chain, which is focused on the discovery of new energy sources and new technologies. The second is a competitive energy market, which takes place for lack of energy deregulation, which allows multiple companies to produce and distribute energy, generating competition that creates the need for regulation of the energy market. In addition, the third is the environmental protection, which is the goal facing the energy market changes and climate change as well. For each of these three major objectives, Patlitzianas et al (2008) recommend some indicators, such as the dependence on imported natural gas, energy generation efficiency, the percentage of renewable primary sources in energy production, and others. From the indicators proposed by Patlitzianas et al (2008), it is possible to visualize the management and organization, installations, technology, logistics and planning production control areas.

4.1 Summary of Cognitive Analysis of Energy Performance Indicators and Decision Areas

Incorporating the extracted relations cognitively, the sets of indicators proposed by these authors, Figure 4 was built, in which the clearer information to note is the lack of indicators to the area of Product Engineering. All other areas, indirectly, appear in some of the proposed indicators, and the main areas are the installations and technology.

| Authors                  | OG | INST | TEC | RH | QLD | LOG | EP | PCP |
|--------------------------|----|------|-----|----|-----|-----|----|-----|
| Patterson (1996)         |    |      |     |    |     |     |    |     |
| Kulkarni e Katti (2010)  |    |      |     |    |     |     |    |     |
| Neves e Leal (2010)      |    |      |     |    |     |     |    |     |
| Wu et al (2007)          |    |      |     |    |     |     |    |     |
| Duflou et al (2012)      |    |      |     |    |     |     |    |     |
| Patlitzianas et al (2008)|    |      |     |    |     |     |    |     |

Figure 4. Summary of decision areas and the studies selected for this research.

It is understood that the energy performance indicators related with installations and technology areas are strongly related to energy variable, since these areas are addressed in the company’s structure, plant size, type of technology used, production capacity, type and degree of automation of the process, these being features that can raise or lower the energy consumption according to the decision. As for the other areas, it is understood that there is subjectivity in energy consumption, however, the idea of this study is even implicitly, extract the relationship between all decision areas and energy performance indicators.

5. DISCUSSION

The study of the impact of variable energy in the industrial environment, arouses curiosity about the relationship between it and the areas of decision, operations strategy, because at the time it is defined a strategic action, it can indirectly cause reactions in this chain, by varying the energy and its impacts. Thus, it is sought to identify these relationships, albeit cognitively, so assertive strategies can be outlined for the use and maintenance of energy in an industrial environment.
From the viewpoint of industrial productivity, to Boyd and Pang (2000) energy should be treated equally like any other input, because according to the linear programming models developed by them, the stock variables, output, labor, electricity consumption, fuel cost and cost of materials, have impacts on productivity and should be treated equally. That is, supported the hypothesis that energy efficiency and productivity are statistically related.

Productivity variation can be considered a determining factor in energy efficiency, and other economic variables such as the price of energy and the variable knowledge that is considered important and consistent for the study of energy management systems (Boyd and Pang, 2000). The results show that plants that adopt best practices are consistently more efficient in energy, holding prices and constant learning. In all cases, the difference in productivity between plants, for example, account for at least a proportional difference in energy intensity (Boyd and Pang, 2000).

Clearly, it can be seen that some of the models presented for energy management in manufacturing environments relate indirectly the decision areas and not in others, it presents this well-defined relationship. However, some may significantly contribute to the development of energy management system operating strategies, indicating best practices and defining performance indicators.

The use of energy consumption indicators in an industrial plant contributes to the reduction of consumption and energy, costs, however, not always, this kind of indicator goes in line with the production. Analyzing literature review raised in this research, we identified a gap in the literature when it comes to energy management in industrial environment and its relation to the decision areas.

It proposes in the present analysis that the model shown in Figure 2 is restructured, expanding the areas of decision already highlighted and clearly defining indicators for each of them. The model proposed by Fenerich et al (2013), has as its main contribution to energy management, and a proposal contemplation that appears in ISO 50001: 2011, with the decision areas, as defined by Skinner (1996), Corrêa and Corrêa (2009). The model presents itself as a research opportunity in Production Engineering. The model allow the definition of the relationship between decision areas and the five perspectives proposed (social, economic, environmental, innovation / learning and internal affairs), which are defined by models BSC performance management (Kaplan and Norton, 1996) and the sustainable perspectives from Neves and Leal (2010).

This proposed model for energy management in manufacturing environments may allow visualization and quantification of the impact that energy efficiency can cause in each decision area. It also emphasizes that the definition of targets, indicators and measures promoting the monitoring process and quantifies the performance of each perspective from which to assess the need for corrections and preventive actions, and again conduct a monitoring.

6. FINAL CONSIDERATIONS

A literature systematic review provided the identification of energy efficiency in studies aimed specifically for industrial environments and their relation to the previously defined decision areas. The areas were aligned with the studies by a cognitive form, as defined in the proposed methodology, as well as the decision areas used in the study.

By reading the texts, it could be observed that none of them explicitly dealt with the relationship between decision areas and industrial energy efficiency. However, by interpreting the same, it was possible create a link between these areas and some studies, so that the gap appears as a search opportunity, since none of the studies exploring the relationship between the areas and energy efficiency. It was proposed that in future studies this relationship could be identified and explored in more detail, creating energy indicators for each of the decision areas, but also highlights the importance of continuous search of the literature using other search terms and even different criteria.

REFERENCES

Abdelaziz, E. A., Saidur, R. and Mekhilef, S. (2011) "A review on energy saving strategies in industrial sector", Renewable and Sustainable Energy Reviews, 15 (1), pp. 150-168.
Boyd, G. A. and Pang, J. X. (2000) “Estimating the linkage between energy efficiency and productivity”, Energy Policy;28(5), pp. 289-296.
Bunse, K. Vodicka, M. Schonsleben, P. Brulhart, M. and Ernst, F. (2011) "Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature”, Journal of Cleaner Production, 19, pp. 667-679.

Choudhari, S. C. (2012) “Exploratory case studies on manufacturing decision areas in the job production system”, International Journal of Operations & Production Management, 32(11), pp. 1337-1361.
Corrêa, H. L. and CORRÊA, C. A. (2009) Administração de produção e de operações: manufatura e serviços: uma abordagem estratégica. 1ª ed. ed. São Paulo: Atlas.
Dorr, M., Wahren, S. and Bauernhansl, T. (2013) "Methodology for energy efficiency on process level", Procedia CIRP - Elsevier, pp. 652 – 657.

Duflou, J. R.; Sutherland, J. W.; Dornfeld, D.; Herrmann, C.; Jeswiet, J.; Kara, S.; Hauschild, M. and Kellens, K. (2012) "Towards energy and resource efficient manufacturing: a processes and system approach", CIRP Annals - Manufacturing Technology, 61, pp. 587-609.

Dusi, B. and Schultz, R. (2012) "Energy management and efficiency - a system approach", IEEE Conference Publication.

Espinosa, F. F. and SALINAS, G. S. (2008) "A model proposition for strategies definition in manufacture process improvement in reference to its environment impact", Rev. Téc. Ing. Univ. Zulia,31(1), pp. 41-49.

Fenerich, F.C. Costa, S.E.G. and LIMA, E.P. (2013) "Proposition of strategic management system for energy", ICPR – Annals – Challenges for Sustainable Operations.

Internacional Organization for Standardization. Energy Management Systems – Requirements with guidance for use: ISO 50001:2011.

Jaffe, A. B. and Stavins, R. N. (1994) "The energy efficiency gap - what does it mean?", Energy Policy, 10(22), pp. 804 – 810.

Kaplan, R. S. and Norton, D. P. (1996) "The balanced scorecard -Measures that drive performance", Harvard Business School (January-February),pp. 71-79.

Kulkarni, V. A. and Katti, P. K. (2010) "Efficient Utilization Of Energy In Industry Energy Management Perspective", International Conference on Power System Technology.

Lombard, L. P., Ortiz, J. and Velázquez, D. (2013) "Revisiting energy efficiency fundamentals", Energy Efficiency, 6, pp. 239 - 254.

Moskalenko, N; Wenge, C; Pelzer, A; Komarnicki, P and Styczynski, A. (2012) "Energy management system with dynamic component control for efficiency optimization", 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), Berlin.

Maturana, H. and Varela, F. (1992) The tree of knowledge: the biological roots of human understanding. Boston: Shambhala, revised edition.

Moreno, J. and Medina, S. (2011) "Energy price variation estimation using an ANFIS model", Rev. Téc. Ing. Univ. Zulia,34(1), pp. 86-93.

Neves, A. R. and Leal, V. (2010) "Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework", Renewable and Sustainable Energy Reviews, 14, pp. 2723–2735.

O’ Driscoll, E., Cusack, D. Ó. and O’Donnel, G. E. (2013) "The development of energy performance indicators within a complex manufacturing facility", International Journal Advanced Manufacturing Technology, pp. 2205–2214.

Palm, J. and Thollander, P. (2010) "An interdisciplinary perspective on industrial energy efficiency", Applied Energy, 87, pp. 3255-3261.

Patterson, M. G. (1996) "What is energy efficiency?", Energy Policy,5(24), pp. 377 - 390.

Patlizianas, K. D. Doukas, H. Kagiannas, A. and Psarras, J. (2008) "Sustainable energy policy indicators: review and recommendations", Renewable Energy, 33, pp. 966 – 973.

Rudberg, M., Waldemarsson, M. and Lidestam, H. (2013) "Strategic perspectives on energy management: a case study in the process industry", Applied Energy, 104, pp. 487 - 496.

Sampaio, R. F. and Mancini, M. C. (2007) "Estudos de revisão sistemática: um guia para síntese criteriosa da evidência científica", Rev. Bras. Fisioter., (11), n°1, jan/fev, pp. (83-89).

SKINNER, W. (1969) “Manufacturing: missing link in corporate strategy”, Harvard Business Review (May-June), pp. (136-145).

Tanaka, K. (2008) "Assessment of energy efficiency performance measures in industry and their application for policy", Energy Policy, 36, pp. 2887-2902.

Wheelwright, S. C. and Hayes, R. H. (1985) "Competing Through Manufacturing", Harvard Business Review(January-February), pp. 99-109.

Hayes, R.H., Wheelwright, S.C. and Clark, K.B. (1988) Dynamic Manufacturing: Creating the learning organization, New York: The Free Press, NY.

Wu, L. M., Chen, B. S., Bor, Y. C. and Wu, Y. C. (2007) "Structure model of energy efficiency indicators and applications", Energy Policy,35, pp. 3768 - 3777.
Appendices A - Decision areas and the features of decisions for each of the areas, by Skinner (1969), Hayes and Wheelwright (1985; 1988).

| Decision Area          | Type of Decision                                                                 | Type of Decision                                                                 | Type of Decision                                                                 |
|------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Equipment and Facilities| Process type, plant size, plant location, investment decisions, choice of equipment, type of tools. | Size, location, specialization, scale, flexibility and interconnectivity.        | Static design, focus, future projects.                                          |
| Capacity               | ---                                                                              | Amount, time and type of process.                                                | Demand arrears, required capital, aimed capacity.                                |
| Planning Production Control| Inventory frequency, inventory size, what control, quality control, use of standards, level of inventory control | ---                                                                              | Centralization, decentralization inherent uncertainties, reducing uncertainty.    |
| Recursos Humanos       | Especificação de trabalho, supervisão, engenharia industrial, sistema de salários | Seleção, treinamento, compensação e segurança.                                   | Redução de habilidades, recursos de energia, desenvolvimentos de competências, recursos de melhorias. |
| Product Engineering    | Size of the product line, technological risks, engineering, use of manufacturing engineering, | Beginning, end and modifications.                                                | Sequencing, parallel activities, interactive team.                               |
| Organization and Management| Type of organization, executives' time of use, degree of risk assumed, type of business, use of employees. | Organization, scales and control.                                                | Fragmentation, engineers, integration, responsible line.                         |
| Vertical integration   | ---                                                                              | Direction, length and balance.                                                    | Minimizing costs, division of responsibilities, skills, search influences.      |
| Technology             | Processes, equipment, critical determinants, materials, trends, degree of mechanization, process extension. | Scale, flexibility and interconnectivity.                                         | Cost cutting, external and internal resources, capacity increases.               |

References
- Skinner, W., “Manufacturing: missing link in corporate strategy”, Harvard Business Review, May-June 1969.
- Wheelwright, S.C and Hayes, Competing through Manufacturing, Harvard Business Review, 1985.
- Hayes, R.H., Wheelwright, S.C. and Clark, K.B., Dynamic Manufacturing, The Free Press, New York, NY, 1988.