A systematic literature review in industrial energy efficiency: an integrative framework

Marcos Gonçalves Perroni
Pontifical Catholic University of Parana
doutorado.perroni@gmail.com
Sergio E. Gouvea da Costa
Pontifical Catholic University of Parana
Federal University of Technology – Parana
s.gouvea@pucpr.br
Edson Pinheiro de Lima
Pontifical Catholic University of Parana
Federal University of Technology – Parana
e.pinheiro@pucpr.br
Wesley Vieira da Silva
Pontifical Catholic University of Parana
wesley.vieira@pucpr.br

Abstract
The objective of this paper is to present the results of a Systematic Literature Review in the field of Industrial Energy Efficiency with the perspective of Energy Management. An integrative framework of how Energy Management can be thought regarding both in the company as in the chain will be proposed**.**

Keywords – Systematic Literature Review, Industrial Energy Efficiency, Energy Management

INTRODUCTION

It is common for a researcher to update the state of the art in relation to a specific field of knowledge. This survey involves mapping the current scientific knowledge with the aim of identifying previous studies. The survey of previous studies is used by the researcher as a map for evaluation of existing intellectual territory. This mapping gives conditions to the researcher to propose original research initiatives that advance knowledge in the specific area (Tranfield, 2003; Luft and Shilds, 2003).

With the advancement of information technologies the mapping task on the one hand, it has become easier due to the adoption of major scientific document databases, but then there is the difficulty of choosing the right work to the objective of the research, mainly due the large amount of existing works, caused by multidisciplinary and fragmentation of fields of knowledge (Tranfield, 2003; Biolchini et al., 2007).

One solution to the above problems has been the systematic literature review (SLR), which is considered an approach to organize and develop a process of literature review. The development of the (SLR) process enables the identification, mapping and analysis of relevant research problem (Tranfield et al., 2003; Kitchenham, 2004; Biolchini et al., 2007).

The energy area presents characteristics of a complex area because there are a number of studies even in their sub-areas. In the analysis of three bibliometric studies comparing the periods 1993-2001 to 2002-2010, we can confirm the growing interest in specific areas of the energy field. In biofuels can be seen a growth of 1310% in publications and 1946% in the number of citations and Boeing Xu (2013), in the energy efficiency field a growth of 278% and 396% Du et al. (2013) and last in solar energy increased by 103% and 187% over the same indicators Du et al. (2014). Based on these studies the field of energy efficiency research has an interest of research higher than in solar energy.

The objective of this paper is to present the results of a systematic literature review for the sub area industrial energy efficiency with the perspective of management. The systematic literature review process was undertaken as a process model developed by Perroni et al. (2015). Based on the systematic literature review of this research field, an integrative framework is presented. This work is divided into four sections: Stage of SLR, results of SLR in industrial energy efficiency, integrative framework and conclusion.

STAGE OF PROCESS MODEL FOR SLR

A systematic literature review in industrial energy efficiency field was undertaken as shown process model in Figure 1. It is not the purpose of this paper to go into detail about the process model for the systematic review, but uses it as a methodological tool to support the results found. As in other works that proposes models for the implementation of SLR (Tranfield et al., 2003; Kitchenham, 2004; Biolchini et al., 2007), the SLR process in Figure 1 is presented in three stages. In the first stage are given the procedures for the selection of the documents so that the set of documents complying with the rules of exhaustivity, representativeness, homogeneity and relevance. In the second stage it is where it happens the procedures for the extraction of information, where the goal is to build two databases called content and citation panel. The databases are analyzed in the third stage through various techniques such as Social Network Analysis (Hansen et al., 2011, Prell, 2012). The ultimate goal is to build an integrative and interpretative framework of the systematic literature review. The framework is integrative because it is a synthesis of secondary research.

In the first stage of the model seen in Figure 1, in order to define the research topic, was made an initial search in books, government agencies reports, International Energy Agency and scientific articles through fluctuating readings. The initial research question was raised: "*How does the energy performance can be measured, taking into account both efficiency and effectiveness in managing the manufacturing*" (Perroni et al., 2014). By building an initial theoretical framework we find the existence of a number of significant works in the field of Industrial Energy Efficiency/Management, where the Science Direct is the database that brings together most important journals in the field, as it has more than 100 journals associated with the energy efficiency.

We decided to use the Science Direct focusing on scientific articles, since they are able to reveal the frontier of knowledge. After several tests, the search terms selected were: ["industrial energy efficiency" OR "industrial energy management" OR "energy efficiency manufacturing"

OR (“energy efficiency” AND “manufacturing”) OR (“energy management” AND “industry”) OR (“industrial symbiosis” AND “energy”) OR (“energy management” AND “manufacturing”)].

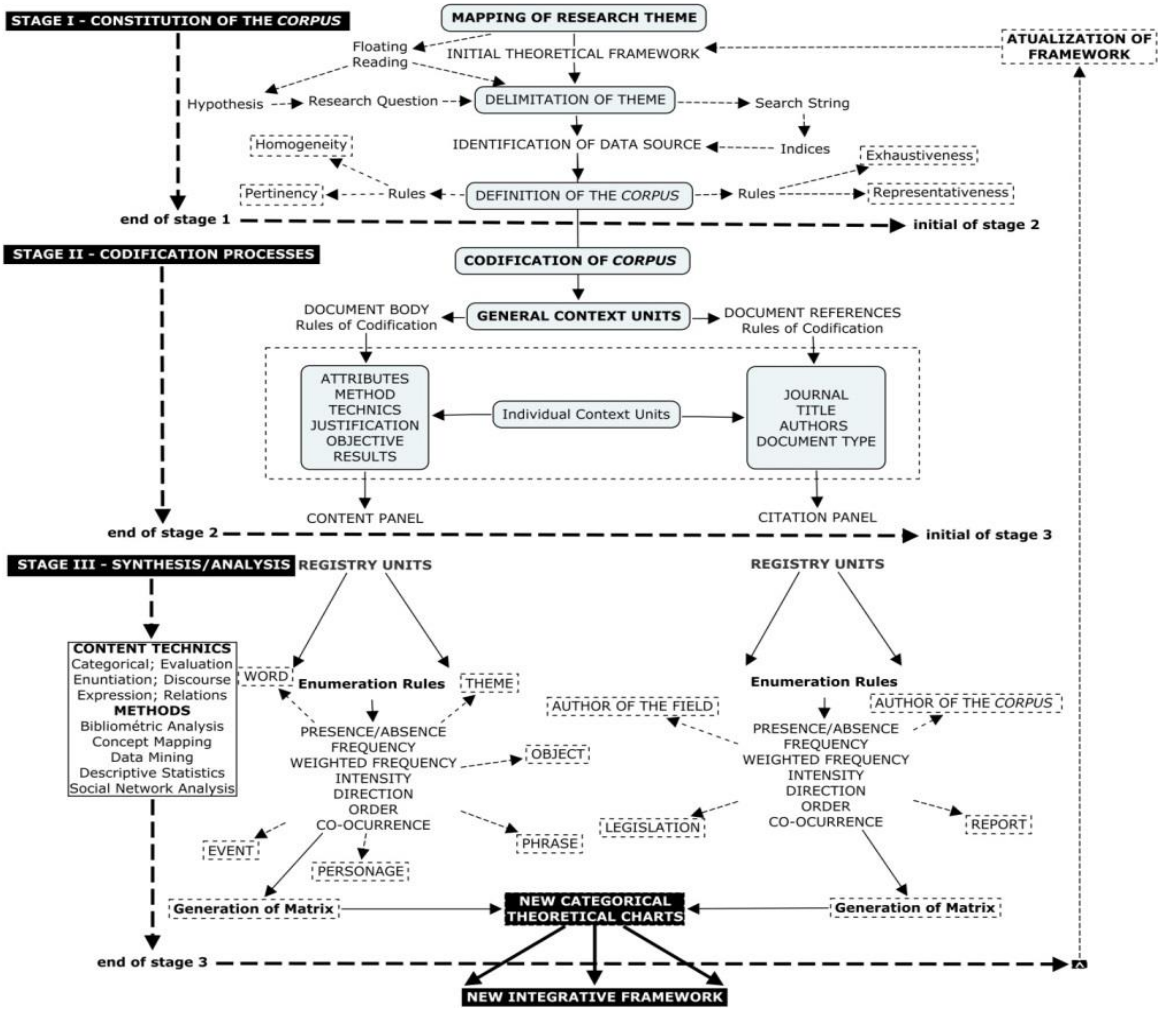

Figure 1 - Process Model for Systematic Literature Review

The scoped the presence indicator was selected the title, abstract and keywords of the articles. The search was carried out during the month of May/2014, returning 574 articles, of which 178 were downloaded based on the analysis of the summary, 104 of 178 articles were selected for setting up the corpus, always observing the four criteria mentioned in the Figure 1 model, ie, exhaustivity, representativeness, homogeneity and relevance, which is consistent with the research question to be answered. The first stage was conducted from April/2013 to May/2014.

As described in the model, the next stage is the codification of the corpus. The initial objective of the coding process is the construction of two databases (content and citation panel). The 104 articles were read, being made extractions for an Excel® spreadsheet. In the content panel were extracted 61,202 words, averaging 588 words per article, minimum 288 words maximum is 985 words. The citation panel was constructed by selecting the first author of each reference. The citation panel totaled 4,466 citations where 1,255 are journals of articles. In implementing the second stage it was spent about 400 hours between June and December 2014.

RESULTS OF SLR IN INDUSTRIAL ENERGY EFFICIENCY

Through the application of the model in Figure 1 it was possible to identify the main theoretical aspects, identifying the categories and themes that the researchers work, pointing an update of the existing framework and highlights trends for future research. Figure 2 shows the network of 104 works of the corpus and Figure 3 the network of themes in which the authors work.

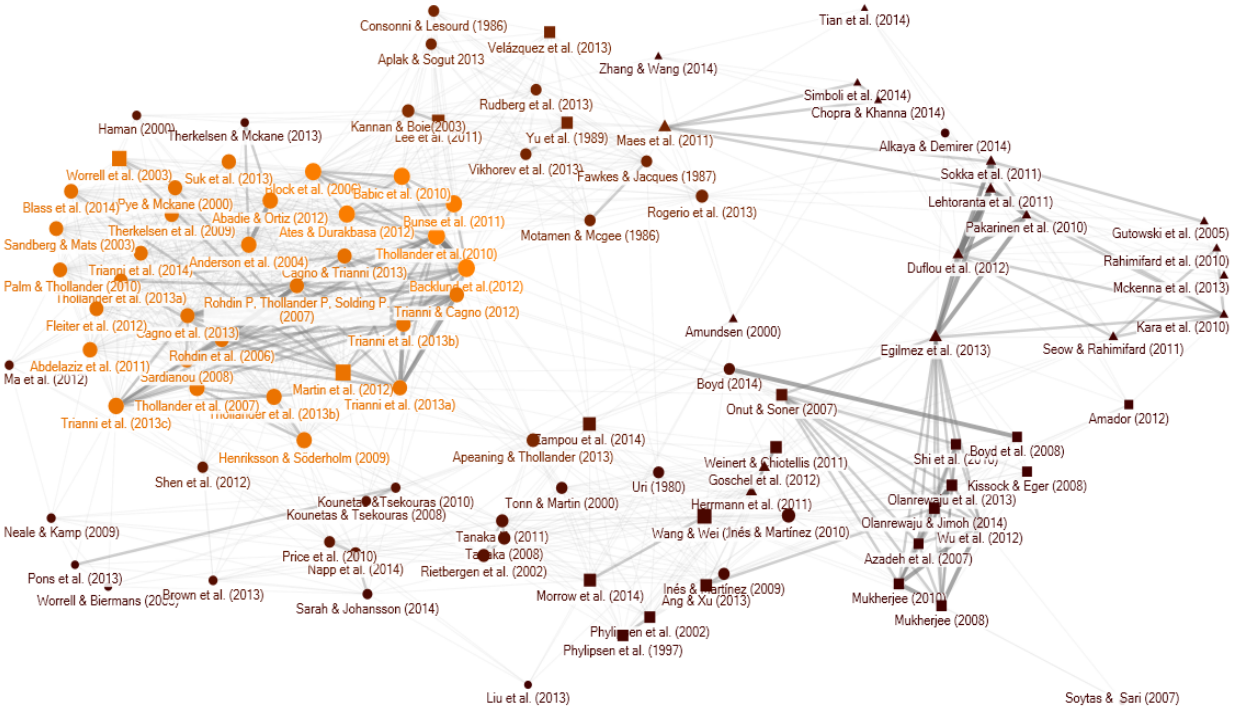

Figure 2 - Network of 104 works of corpus based on the work themes

Based in Figures 2 and 3 the literature works with three main categories: Energy Efficiency/Management (disk), Performance (square) and Sustainability (triangle). The orange color in Figures 2 and 3 represent the most central themes and authors based on the statistical social networking eigenvector centrality. According Prell (2011) the centrality are important because the more central is an individual the greater its influence on the group. Figure 2 shows that the authors who work with energy efficiency and management are more central. In Figure 3 the centrality is divided among the three groups.

The group energy efficiency/management involves 63 of 104 articles. The most central themes of this group are: Energy Efficiency Measures (EEMs), Barriers, Energy Efficiency Gap and Energy Management. The strongest links occur between Barriers, EEMs and Energy Management as can be seen in Figure 3.

According to Patterson (1996) efficiency in the context of energy is a generic term and there is no single measure. The efficiency is related to the use of fewer inputs (energy) while maintaining constant output. For Paterson (1996) the energy efficiency indicator is the ratio output/input, classified into four groups: Thermodynamic, thermodynamic-physical, economic-thermodynamic, economic.

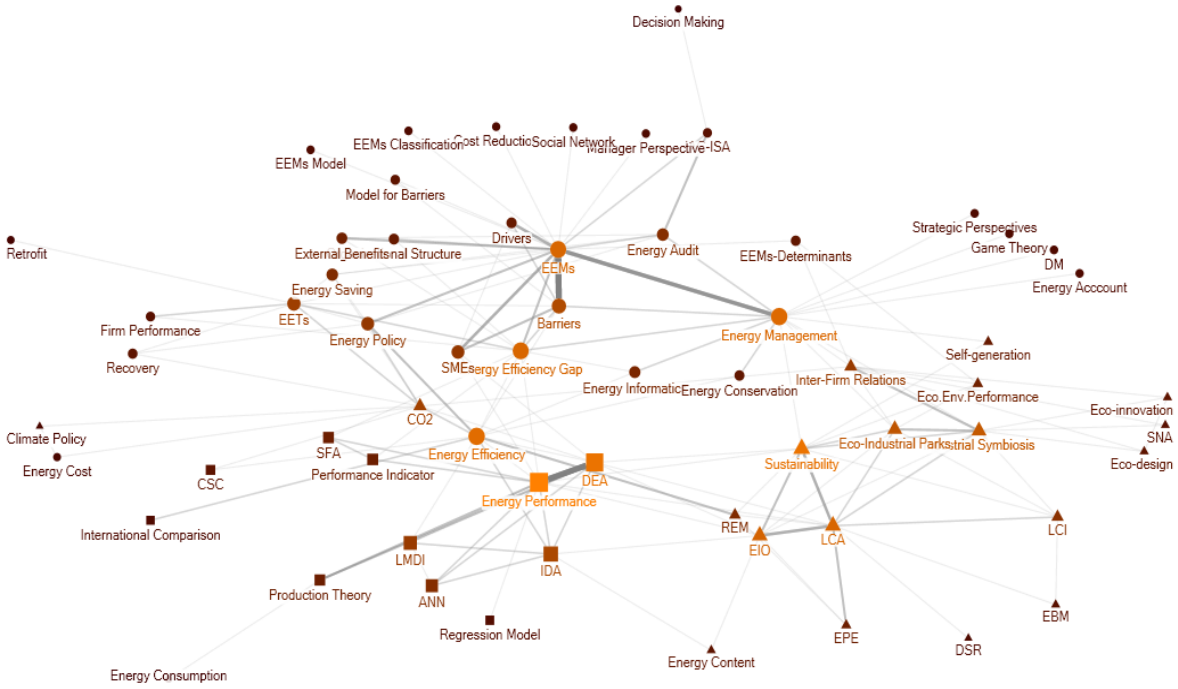

Figure 3 - Relationship between 63 themes identified in the corpus

The connection between the concept of efficiency and energy management can be interpreted according to the definition of Bunse et al. (2011, p. 668) "*In our research we define 'energy management in production' as including control, monitoring, and improvement activities for energy efficiency*". Based on research, Backlund et al. (2012) both policy documents and scholarly literature recognizes the existence of so-called energy efficiency gap, which is related to non-implementation of energy efficiency measures (EEMs), even if cost effective.

The most of the works of the energy efficiency group are concerned to explain the determinants where energy efficiency and energy management have been implemented, and the difficulties through barriers encountered. A representative work of the study of barriers is the work of Cagno et al. (2013), which by means of a literature review developed a model to study the barriers: (a) Technology-related barriers [technologies not adequate; technologies not available]; (b) information barriers [lack of information on costs and benefit, information not clear by technology suppliers; trustworthiness of the information source; information issues on energy contracts]; (c) Economic [low capital availability; investment cost; hidden costs; Intervention-related risks; external risks; intervention not sufficiently profitable], (d) Behavioral [lack of interest in energy efficiency; interventions; other priorities; inertia; imperfect evaluation criteria; lack of sharing the objectives] (e) Organizational [low status of energy efficiency; divergent interests; complex decision chain; lack of time; lack of internal control] (f) Barriers related to competences [identifying the inefficiencies; identifying the opportunities; implementing the interventions; difficulty in gathering external competences] (g) Awareness [lack of awareness or ignorance].

The model of Cagno et al. (2013) is an evolving decision model for the implementation of EEMs, where companies are more susceptible to barriers of awareness and behavioral in the early stages, organizational barriers and information at intermediate stages and economic,

technological and competence barriers in stages of greater maturity. The model, Cagno et al. (2013) recognize the interaction between barriers in various stages of decision-making

The main conclusion of virtually all studies that try to investigate the adoption of the measures in energy efficiency and energy management (EEMs) is that the practices and technologies for energy efficiency (energy efficiency technologies - EETs) have not been fully adopted, and the correlation between the investment for a greater energy efficiency and the economic and financial performance are not always clear, generating positive and negative results, depending on the analysis conditions (Anderson et al., 2004 Kounetas and Tsekouras, 2010).

Extending the question of efficiency, several studies have surveyed both the implementation as the frameworks proposition for the energy management (Kannan and Boie, 2003; Christoffersen et al., 2006; Babic et al., 2010; Thollander and Otosson, 2010 , Backlund et al., 2012). Christoffersen et al. (2006) concluded that between 3% and 14% of companies have practiced energy management in Denmark. Considering Swiss intensive industries such as paper and foundries Thollander and Otosson (2010) found that 40% and 25% respectively practiced energy management. Some studies as Kannan and Boie (2003) and Babic et al. (2010) propose frameworks for energy management for companies, where the energy audit is an intermediate technique of the evolutionary process. According with Kannan and Boie (2003, p. 948) "*The aim of an energy audit is to scan areas for possible energy savings or analysing individual energy saving measures [1]. An energy audit may be considered as similar to the monthly closing statement of an accounting system*".

In a broader aspect the main concern of the performance group is to propose models for measuring energy performance (Phylipsen et al., 1997; Azadeh et al., 2007; Boyd et al., 2008; Olanrewaju et al., 2013; Egilmez et al., 2013). It can be clearly seen in Figure 3 that the method most used by the authors of this group is the data envelopment analysis (DEA). Other methods are also used as: Economics Input Output (EIO), Stochastic Frontier Analysis (SFA), Logarithmic Mean Divisia index (LMDI), Artificial Neural Network (ANN), Social Network Analysis (SNA), among others. Although most of these studies conclude that the methods are effective for measuring energy efficiency, the test of models are usually made on aggregated data because of the difficulty of finding data available at the enterprise level.

The sustainability group uses a number of concepts that relates the demand for energy with a broader aspects involving the life cycle of goods and services (Life Cycle Analysis - LCA) and environmental impact (Gutowski, et al., 2005; Kara et al., 2010; Duflou et al., 2012) energy saving through collaborative processes such as industrial Symbiosis in industrial Eco-parks (Sokka et al., 2011; Pakarinen et al., 2014) dematerialization through the reuse of materials (direct secondary reuse - DSR) (McKenna et al., 2013).The methods used by the sustainability group has the characteristic to involve more than one actor, as a group of companies or chain, representing a flow. The effective energy savings is achieved when there is a collaboration as in the Industrial Symbiosis (Sokka et al., 2011).

AN INTEGRATIVE FRAMEWOK

An important question is the representation and integration the three groups mentioned in the previous section. The primary purpose of a systematic literature review is to provide a more reliable process, safe and capable of being reproduced by other researchers, identifying the theoretical framework of the area. A systematic review showed that studies in industrial energy

efficiency are in three areas: Management and Efficiency, Sustainability and Performance. Figure 4 draws a framework that integrates the literature in three different levels.

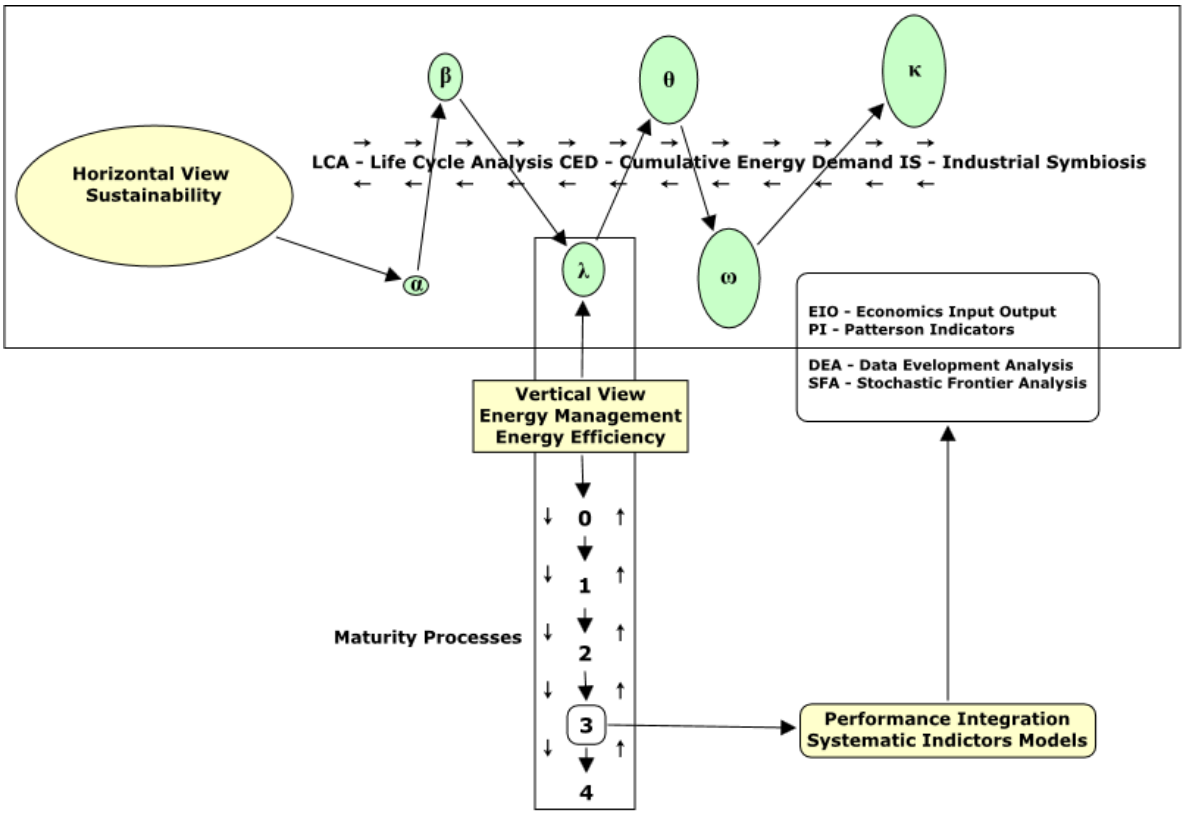

Figure 4 - Integrative framework for industrial energy efficiency

The vertical level represent the works of group of the efficiency and management. Among the main themes that this group survey, are the studies of the barriers that limit the efficiency in which the main work is Cagno et al. (2013). For the representing of energy management can be selected the works of Kannan and Boie (2003) and Babic et al., (2010). Something common in this work is the perception of a process of maturity for industrial energy efficiency through the implementation of energy management, in order to achieve continuous improvement. These articles are very similar to the model developed by Ngai et al. (2013) where the management of energy and utilities evolves from an early stage where there is no management actions to a stage of performance-based management. The values 0-4 in Figure 4 of the framework represents the evolution. Specific names were not placed because different articles identify different names. In Babic et al. (2010) the change in stages occur throughout the business structure: Energy management policy, organising, staff motivation, tracking, monitoring, and reporting systems, staff awareness and investment. The work Ngai et al. (2013) defines specific names for the stages: Initial, managed, defined, quantitatively managed and optimized.

The vertical viewing occurs for λ component, but within the horizontal view the λ is only one enterprise component. When it has more than one component the energy study gains new concepts and techniques as (LCI LCA) (Gutowski et al., 2005; Kara et al., 2010; Duflou et al., 2012), Industrial Symbiosis (Sokka al., 2011; Pakarinen, et al., 2010) and dematerialization through the reuse of materials (DSR) (McKenna et al., 2013).The idea of horizontal vision in the integrative framework of Figure 4 is that each system component (α, β, θ, ω, κ) have to be

concerned not only with your process, but with the whole system, either in the industrial symbiosis or in the life cycle of their products and services.

Many models for the quantitative measurement of the energy performance are proposed by group of the performance (Phylipsen et al., 1997; Azadeh et al., 2007; Boyd et al., 2008; Olanrewaju et al., 2013; Egilmez et al., 2013). The big problem is that the implementation of these models cannot be made in companies that have no concern for energy management. Some barriers related to behavior and consciousness has to be removed, since there is the need for planning for data collection, disaggregation problems of data by industries or processes and actions to be taken once measure by measure may not be useful. Another issue is that there are systems of indicators oriented at the enterprise level as the DEA and the SFA and indicator systems as the economic input-output analysis (Egilmez et al., 2013) facing the analysis of more than one participating unit as a chain or group of companies.

CONCLUSION

The process of systematic literature review identified three groups in the area of industrial energy efficiency, which study different problems. The Energy Efficiency/Management group identifies a series of barriers that limit the implementation of measures and actions for energy efficiency, which in practice has occurred, since in none of the work was found complete energy management systems. The group of performance offers models for quantitative measurement, but overall applications are made with aggregate data. In sustainability group despite having been found concepts such as the cumulative energy demand (CED) and industrial symbiosis (IS) is lacking clear analysis models how energy can be thought as an integrated system.

The integration of the contributions of the work of these three groups can be seen in Figure 4. The interpretation of Figure 4 is that, a system for effective industrial energy efficiency requires both individual management programs and setting up a system of indicators able to meet both the individuals how interest of chain. The model in Figure 4 has shed light on the need to develop more integrative models from the standpoint of effective energy efficiency improvements.

Acknowledgments

This work was conducted during a scholarship supported by CAPES – Brazilian Federal Agency for Support and Evaluation of Graduate Education within the Ministry of Education of Brazil.

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