Energy Efficiency and Greenhouse Gases Emissions in the Appliance Industry: The First Brazilian Case Study

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ABSTRACT

This work presents the innovative emissions reduction work performed at MULTIBRÁS' industrial facility in the state of Santa Catarina (SC) – Brazil. MULTIBRÁS is Brazil's leading refrigerator manufacturer and a subsidiary of the Whirlpool Corporation. The work scope was comprehensive, including activities to evaluate the current energy efficiency level of the plant, to provide tools for monitoring and improving efficiency levels over time, to evaluate the associated greenhouse gas emissions and to develop the awareness and educational program for the employees as well. The innovation of the work done was not only to perform some activities for the first time in Brazil, but also to apply a complete set of integrated activities in the same factory.

The energy audit comprised parts of utility equipment systems in the plant (compressed air, lighting, transformers and electric motors) and electricity billing analysis. Estimated energy savings were up to 3,734 MWh/year, representing a 4,6 % reduction of the 1999 total energy plant consumption and 24 % of the total analyzed consumption. Estimated financial savings were up to R$[1] 294,245/year reduction in electricity bill. Total investment for proposed measure implementations is about R$ 476,000 with average payback time of 25 months assuming a 16% discount rate.

Greenhouse gases emissions avoided by such actions were investigated under three different scenarios of Brazilian future energy production.

The performance indexes study segmented the factory in macro areas. The efficiency profile analysis of these areas showed a different behavior throughout the year, identifying areas that most influenced the overall plant energy efficiency. A methodology to manage the electric energy consumption to improve productivity was implemented.

Introduction

Reducing energy waste must be approached as a new business opportunity. Future challenges on energy issues to be faced by the power sector are reinforced by an increasing governmental trend to establish rigid environment controls. During the last decade, PROCEL - Brazilian Energy Conservation Program has been intensifying its activities in several sectors with CEPEL's (Electric Power Research Center) technological support.

Among several activities, implementing and tracking an energy optimization plan on the customer's side, effectively measurable, is one of the most important areas of opportunities, especially in the industrial sector. At the beginning, this activity was

[1] U$ 1.00 = R$ 2.00

developed based on acquired experience, having started up with energy audit typically in electric systems. Currently, monitoring and tracking tools go with performance indexes, and greenhouse gases emissions assessments are being added to this activity. A project like this one can only be successful if the industrial partner accepts energy efficiency as one of the core management values, as opposed to solely assessing the economic return for these types of projects in the same way as any other internal project. In fact, this is the case of MULTIBRÁS S.A., and its parent Whirlpool Corporation that is a member of the Business Environment Council of the Pew Center on Global Climate Change.

This paper describes the innovative experience of MULTIBRÁS in its Joinville/SC plant. The project scope was designed to be comprehensive, anticipating activities not only to evaluate the current energy efficiency status, but also providing tools for its management. The first activity consisted of an energy audit to evaluate the current level of waste in the chosen subsystems in the Joinville/SC plant. At the same time, a second activity was performed in order to establish a management energy group based on energy index monitoring and on the Energy Efficiency Measures Implementation Plan, which enable energy efficiency level continuous improvement. The third one was an environmental benefit evaluation in which were investigated the expected reduction in greenhouse gases emissions. To keep the employees' commitment with the project, it was concluded with an awareness and educational program. The aim of project methodology was to motivate replication in other areas in the same plant and for other industrial plants as well.

Energy Audit

The methodology used to accomplish the energy audit followed basically the following steps:

- Technical visit for general acknowledgement of industrial plant operation;
- Plant production data and technical documentation surveys;
- Plant energy consumption analysis;
- Equipment data survey and information on operation cycles ;
- Lighting and air conditioning system survey;
- Equipment and plant facilities measurements;
- Analysis of all gathered data;
- Final report issue and presentation;

The energy audit was subdivided into several distinct systems, such as lighting system, electric motors, transformers, refrigeration and air conditioning, compressed air, equipments' operation cycle and electric energy billing analysis.

Performance Indexes for Energy Management

The implementation of energy management in Joinville's industrial facility through the indexes and targets plan may highlight the forward thinking nature of the appliances sector in the country from now on, especially because this is the first plant to implement such an approach in Brazil. The production process analysis was accomplished by segmenting the plant into 12 sections. The following step was to develop a measurement plan, which

consolidated the chosen indexes, both in the short and medium term. For each section, a manager was assigned to be responsible for the energy target. The complete energy management methodology is shown in Figure 5.

The linear regression analysis concerning consumption and production required the withdrawal of some data from historical sources, in order to obtain a reliable correlation factor. This paper presents the results of efficiency profile analysis of the global plant, Factory II and Factory III, which are called the main macro areas.

Environmental Impacts - Evaluation and Assessment (estimated in terms of greenhouse gases emissions reductions).

Calculating and correlating the environmental benefit from the energy savings, in terms of greenhouse gases emissions reduction, is an important innovation. Three different scenarios were developed and the underlying logic for each scenario is as follows.

The basic assumptions for the three scenarios were:

- Base Year – 1998- chosen to be consistent with PROCEL's study about CO_2 equivalent emissions caused by Brazilian electric energy generation (Rovere and Americano 1999);
- The source of all electrical energy consumed by MULTIBRÁS is the Brazilian interconnected power system which generated around 308 TWh in 1998 and produced 19,020 kton of CO_2 equivalent emissions in that year according to a PROCEL study;
- MULTIBRÁS (Joinville Plant) consumed almost 76,000 MWh in 1998. Considering 15 % as the average transmission and distribution electrical losses, the Brazilian power system had to produce around 90,000 MWh only to supply MULTIBRÁS consumption. Therefore, 5.518 kton of greenhouse gases emissions were associated with the MULTIBRÁS electric energy consumption. This would amount to 55 thousand tons in a ten year's planning horizon, considering as if the plant consumption and the electricity mix remained constant;
- The energy savings obtained through the implementation of ELETROBRÁS/CEPEL and MULTIBRÁS energy efficiency actions were 3,734 MWh/year. This saved energy would require the generation of 4393 MWh, assuming the same average losses of 15%.
- This energy savings, when obtained, means that MULTIBRÁS would reduce or avoid the emissions of 271 tons of CO_2 equivalent in the atmosphere each year (assuming that both the energy savings and the generation profile remained constant).

Given these preliminary assumptions, three scenarios were developed for the emissions associated with the MULTIBRÁS plant. In the first one, the low emissions scenario, it was assumed that the electricity supply to MULTIBRÁS comes from the Brazilian interconnected power system with the 1998 source generation mix (considering electrical energy from different sources) and this assumption was frozen throughout the timeframe of the study. This assumption, clearly unrealistic, served to provide a low emissions scenario as it was based on predominantly hydroelectric generation for the

Brazilian power sector. In PROCEL's study (Rovere and Americano 1999) all power plants emissions were accounted for, including the hydroelectric plant emissions, which are very low if compared to thermal plants' ones. Although there is a recent evidence that certain Amazon hydro plants, in fact, can generate non-negligible amounts of greenhouse gases emissions.

The second scenario is considered the high emissions one. It supposes that the energy savings obtained from 2001 through 2002 come from the Brazilian power sector as in the preceding scenario, e.g., with the same 1998 generation mix. It has the same initial characteristics as the first (for the years 2001 and 2002), but it is assumed that the basic generation source changes drastically from 2003 on. In that year, according to the ELETROBRÁS' Ten Years' Expansion Plan (ELETROBRÁS 1999), the Joinville natural gas thermal plant starts in operation. This plant will be geographically close to the MULTIBRÁS Joinville plant, and will supply the local expansion of electricity consumption. In this second scenario it is assumed that the energy saved by MULTIBRÁS Joinville plant, beginning in 2003, would come from that plant. This is based on the following rationale: when factories expand their energy needs, they increase the electricity demand, and this stimulates the increasing of energy supply through the building of new plants. Therefore, the virtual energy provided by the energy efficiency projects competes with the new sources of real energy, postponing the entrance in operation of new plants. In this sense the avoided energy consumption derived from energy conservation is equivalent to the real energy coming from the new plants. The additional energy to supply a possible MULTIBRÁS plant expansion can be thought of as coming from the Joinville gas plant.

In this second scenario, therefore, a natural gas plant would supply the saved energy. That is why it was considered as the high emissions scenario. In this case, all avoided emissions, from 2003 on, would come from a thermal plant. This is also an unrealistic scenario, because that single thermal plant would necessarily produce not all the MULTIBRÁS plant electric energy consumption as the Brazilian power system is interconnected. In light of the difficulties with both the high and low emissions scenarios, it was felt that a medium emissions scenario should be added.

Accordingly the third scenario – the medium emissions one - in which the emissions avoided by the energy efficiency actions vary each year, because each year new plants enter into operation, regarding the energy source profile forecasted in the ELETROBRÁS' Ten-Years' Expansion Plan (ELETROBRÁS 1999). The electricity source "composition" of each avoided kWh and each ton of equivalent CO_2 reductions, therefore, change each year during the time frame of the emission evaluation study.

In the Achieved Results section, the results for the three scenarios are presented. In all three, the energy savings were constant because they derived only from the complete implementation of ELETROBRÁS/CEPEL's measures. These measures arose from studies performed in about 20% of the total area of the MULTIBRÁS plant. Therefore, it was estimated that the total energy savings and emissions reductions would be five times greater in case energy efficiency measures were extended and implemented in the whole plant.

Achieved Results

As the evaluation of the electric transformers indicated that energy conservation measures applied to this equipment were unfeasible, they were excluded from this paper, as they don't contribute to the energy efficiency at all. The energy audit included about 19% of

the electric power consumed in Joinville's industrial plant. The estimated energy savings (SOARES, G. et al. 2000) were up to 3,734 MWh/year, representing a reduction of about 24% for the analyzed areas or 4.6 % of the 1999 MULTIBRÁS energy total consumption. In financial terms, the estimated savings was up to R$ 294,245/year, representing a reduction of 5.3% in the electric energy cost. The total investment was estimated about R$476,000[1]. The average time of payback was up to 25 months assuming a discount rate of 16%. The payback times were much shorter for the air-compressed system.

Table 1 shows the results of the energy audit per analyzed equipment system. The avoided emissions calculations were based on the more conservative scenario, scenario 1.

Table 1. Summary of the Results of Energy Audit

Analyzed Item	ANNUAL SAVINGS		CO_2 AVOIDED	Investment	Payback[2]
	(kWh)	(R$)	ton / year	(R$)	(months)
compressed air					
Inlet air temperature reduction	60,000	4,046.00	4.4	4,000.00	14
Leakage elimination	1,392,000	93,888.00	101.0	70,000.00	11
Centralized control	440,000	29,674.00	31.9	32,000.00	16
Total	**1,892,000**	**127,608.00**	**137.3**	**106,000.00**	**12**
Electric Motors					
Replacement of used motors	187,287	12,631.00	13.6	26,757.00	34
Pumps Turn-off	383,815	25,885.00	27.8	6,900.00	4
Total	**571,036**	**38,516.00**	**41.4**	**33,655.00**	**13**
Lighting					
Lamps & reactors Replacements	650,993	43,703.00	47.3	130,000.00	40
[3]Lamp Retrofit in deposits	619,747	84,418.00	45.0	206,119.00	53
Total	**1,270,740**	**128,121.00**	**92.3**	**336,119.00**	**45**
Summation of all recommended measures					
Total	**3,733,776**	**294,245.00**	**271**	**475,774.00**	**25**

[1] US$ 1.00 = R$ 2.00

[2] For a discount rate of 16%.

[3] The audit recommendations regarding the lighting system motivated MULTIBRÁS' technical group to develop a retrofit study on lamps.

Figure 1 illustrates the share profile of each system in the total estimated energy savings by ELETROBRÁS/CEPEL and MULTIBRÁS' audit. The main contributions came from the air-compressed and the lighting systems.

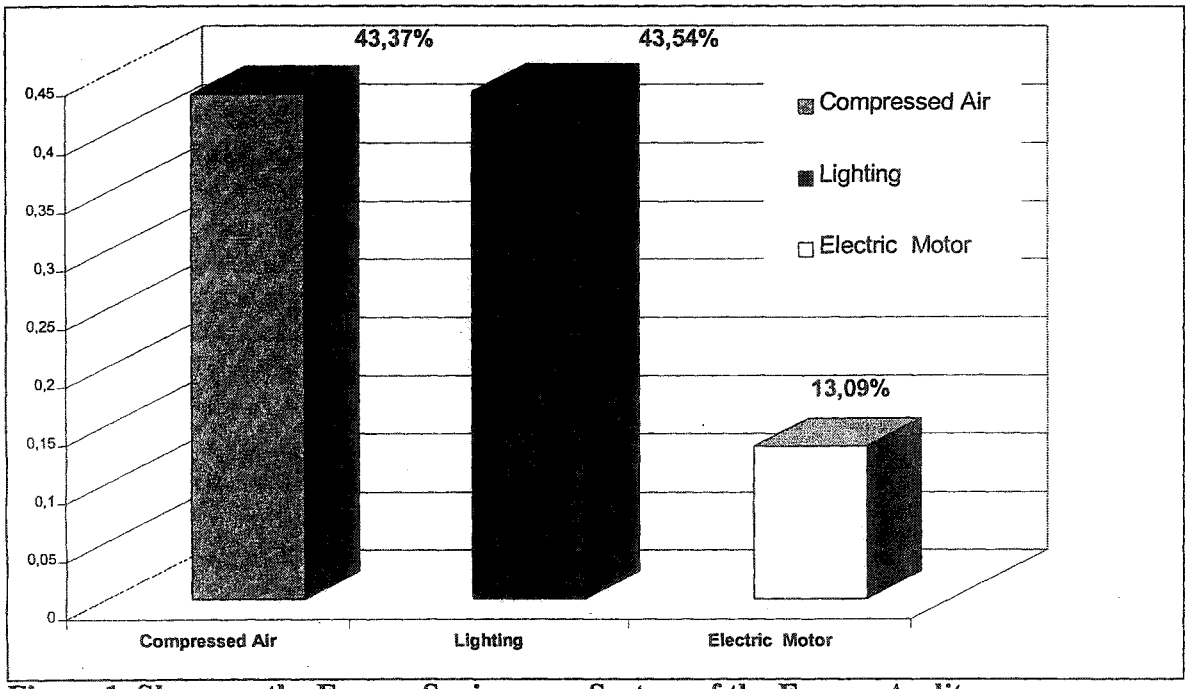

Figure 1. Share on the Energy Savings per System of the Energy Audits

Figure 2 shows the performance profile of the global Joinville's plant. These values represent the energy consumption behavior (relation between the real and forecasted consumption), in a monthly basis, related to the background. For instance, the global plant can be considered inefficient in a certain month, related to the background, if the value is positive, e.g., it consumed more energy than was forecasted. Some results of the study to implement the performance indexes are shown in Figures 2, 3 and 4. They are related to the whole plant, Factory II and Factory III. The other nine areas are not included in this paper as they are not necessary to present the energy management methodology.

The following comments arise from the indexes analysis:

- Joinville's plant in 1999 exhibited different efficiency behaviors along the year. In the first semester, there were sudden changes of efficiency. In Jan/99, the plant improved its efficiency in 15.53% regarding the consumption background, and in the following month (Feb/99), this index became 16,11% worse than the background. On the other hand, in the second semester, the indexes changed less but they still showed some degree of inefficiency status almost all the time.
- Factory II's behavior led to the conclusion that this factory dominated the energy efficiency profile of the entire plant. The expressive share of this sector in MULTIBRÁS' Joinville plant total consumption explained this.
- Factory III's profile showed a positive performance, operating efficiently for 11 months, demonstrating that it should be not the first priority in the energy

conservation plan. This behavior could be explained by the characteristics of more modern facilities compared to a small mix of manufactured products.

A better understanding of Factory II's behavior will be possible when the measurement plan inside it is implemented. This action will allow the identification of the energy "villains".

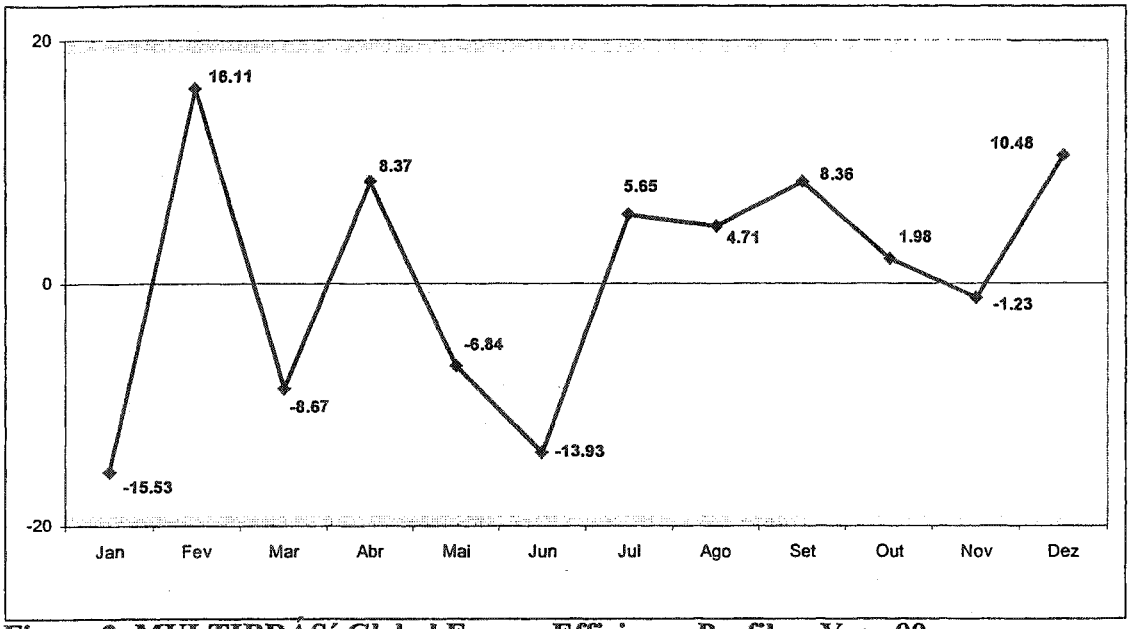

Figure 2. MULTIBRÁS' Global Energy Efficiency Profile – Year 99

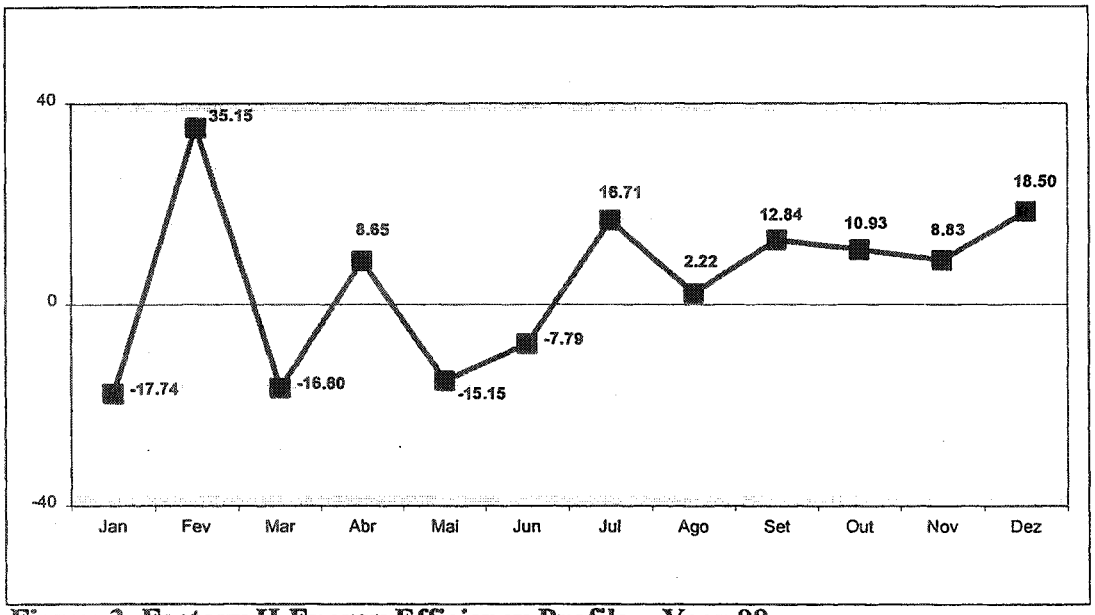

Figure 3. Factory II Energy Efficiency Profile – Year 99

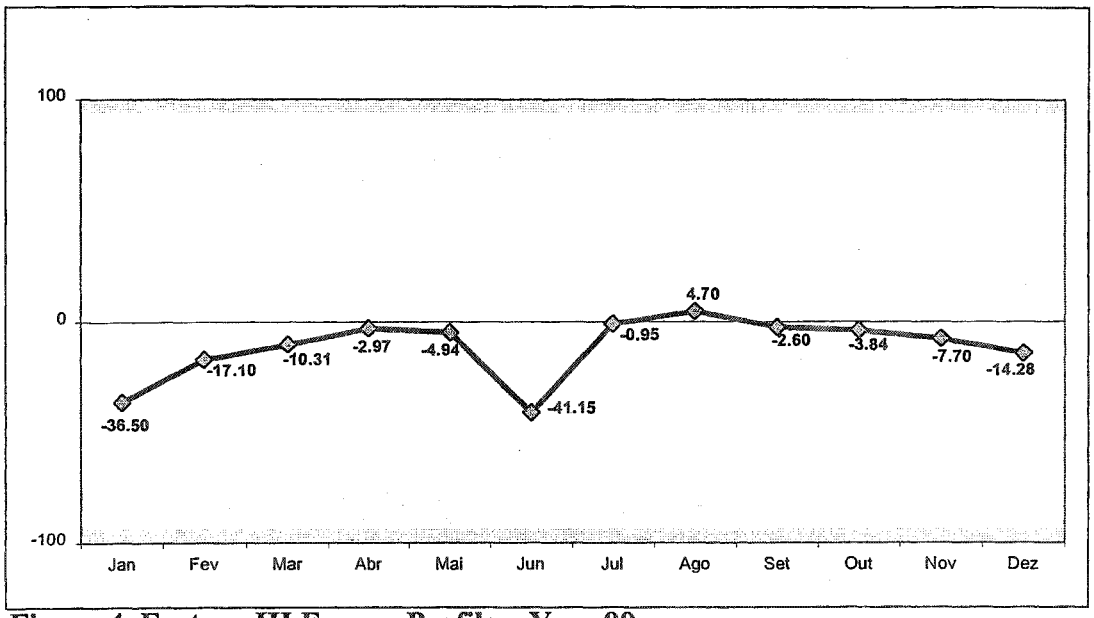

Figure 4. Factory III Energy Profile – Year 99

For each selected area, a manager was assigned to receive the index monthly and to be responsible for figuring it out. The follow-up of this index will increase the productivity by greater understanding of the reasons of inefficiency in a certain month as well as establishing targets for next months. Figure 5 summarizes the complete energy management process.

With respect to greenhouse gases emissions evaluation, Table 2 summarizes the assumptions under the three different scenarios and their results.

Table 2. Estimation of Avoided Equivalent CO_2 Emissions in Ten Years

Scenario	Characteristics of generation	Definition	Avoided emissions (ton/year)
Scenario 1 Low scenario	Remain hydraulic in the same percentage levels of the base year	2001 to 2010 – mix of generation remained the same of 1998.	2710
Scenario 2 High scenario	Full thermal after 2003	2001 and 2002 – hydraulic and 2003 to 2010 – thermal expansion	6573.2
Scenario 3 Medium scenario	2001 to 2010, the mix of the generation changes itself year by year	Changes based on Ten Years' Expansion Plan of ELETROBRÁS	3837.9

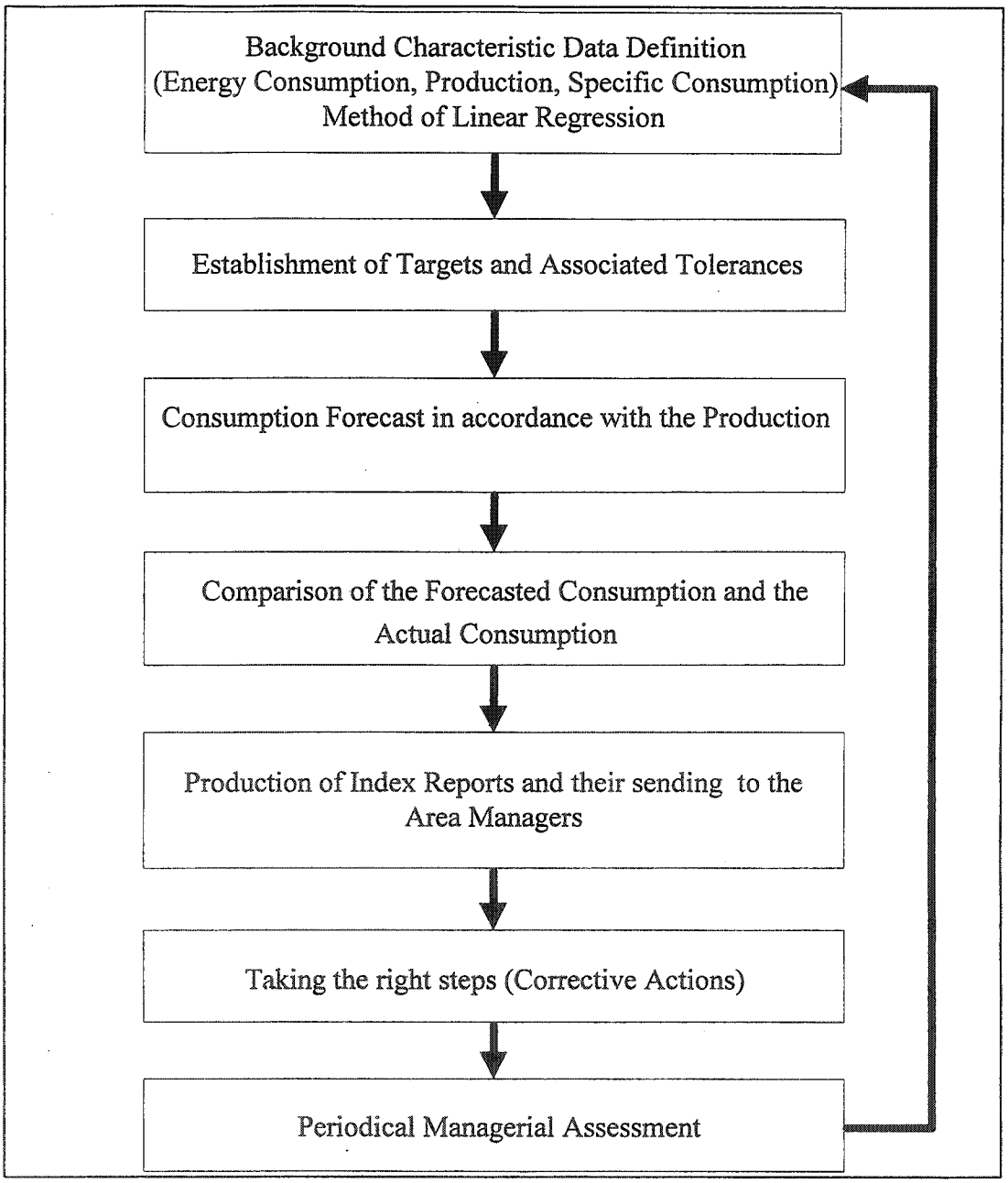

Figure 5. Methodology for Energy Management through Performance Indexes

Figure 6 shows the evolution of the accumulated avoided emissions of CO_2 along the ten reference years. Scenario 1 must be considered the most conservative, as the changes of the power sector reflect a change in the generation mix toward more thermal. Some specialists, arguing that the generation's expansion will be almost completely thermal have defended scenario 2, considered as a "high scenario" in this paper. Scenario 3, reflecting the national generation expansion planning (ELETROBRÁS 1999), is believed to be the most realistic, however the specific energy supply of a certain industrial unit can have different source composition from the electric power grid as a whole. The total potential of

accumulated tons of equivalent CO_2 avoided in 2010 for Scenario 3 in the Joinville's plant would be up to 11,513 , if measures of efficiency are extended to the entire facility.

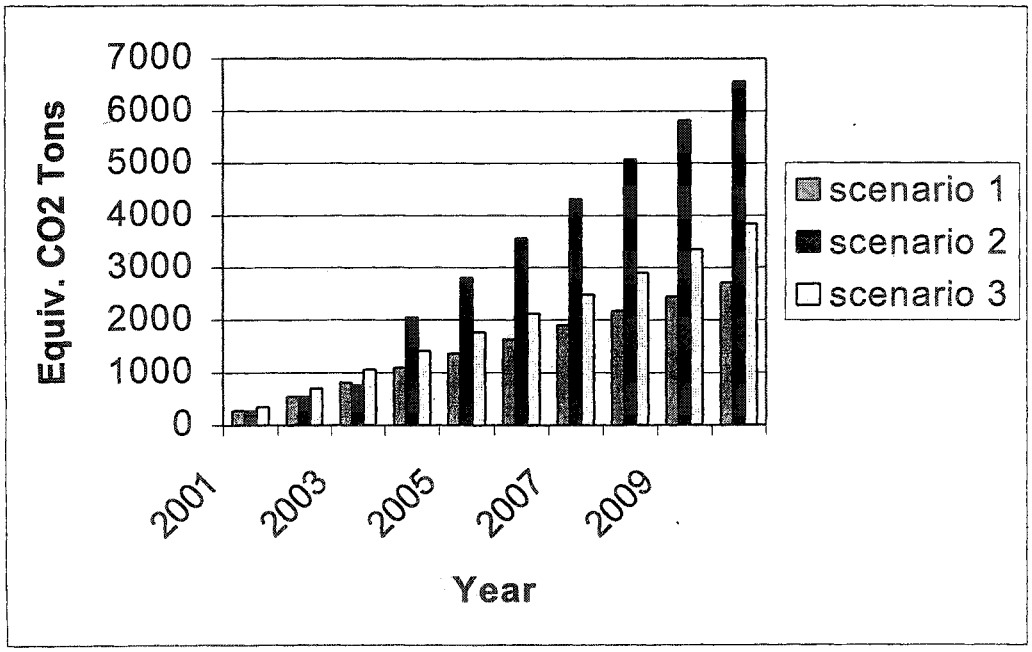

Figure 6. Accumulated Avoided Emissions Evolution along Ten Years in the Three Scenarios

The success of the awareness and educational program on energy efficiency was strongly associated with the explanation of the "reasons" for developing it. To make the involved employees aware, two 8 hours workshops took place in MULTIBRÁS' facilities. The activities based on pedagogical techniques were carried out. Dynamic group task, discussions and games dealt with important issues such as the Brazilian energy panorama, environmental and energy concepts and principles as well as their relation to energy efficiency and human behavior changes were among the ideas presented. The qualified information about the reason for energy conservation activities consolidated the motivation for, and willingness to fully adopt the measures implementation plan. This pre-work also affirmed the commitment to continue the necessary actions to achieve the expected results.

Energy Efficiency Measures Implementation Plan

MULTIBRÁS developed an implementation plan of the recommended measures. They were divided into short, medium and long-term actions. The classification was based on the execution time, short meant less than 1 year, medium between 1 and 3 years and long more than 3 years. The audit recommended 25 technical actions. From this total, 20 were considered feasible to implement. Among them, 10 actions were defined as short term, 6 defined as medium term and 4 as long term. The measures per system were distributed as 4 tasks in the lighting system, 3 in the air compressed system, 11 in the tower cooling system and 2 in the measurement plan.

Conclusion

This paper presented the innovative, integrated and comprehensive approach to energy conservation performed by ELETROBRÁS and CEPEL in the MULTIBRÁS facility. The overall scope of activities was pioneering in Brazil. Energy waste based on current practices was evaluated and the greenhouse gases emissions impact over ten years period was assessed considering three different Brazilian power generation mix scenarios. Another innovative feature of this work included the first Monitoring and Targeting Plan on energy efficiency at plant level focused also on emission reduction in the appliance sector in Brazil. The awareness and educational program plus the complete engagement of the management staff were fundamental for the success of the project. Previous programs of a similar nature faced some problems, such as factory management commitment to implement actions, maintenance of efficiency over time, difficulties in obtaining engagement of the managers and employees in the energy efficiency tasks due to the focus on production issues. The project developed in MULTIBRÁS minimized all these difficulties.

The assessment of avoided greenhouse gases emissions provided another perspective to this task and was undertaken in response to the Kyoto Protocol and the possibility that it will establish international rights and responsibility to reduce global emissions. Under the Kyoto Protocol, the Clean Development Mechanism (CDM) was created which would allow exchanges of greenhouse gases reduction certificates or credits between developed and developing countries. Although energy efficiency area is one of eligible areas for CDM application, as the developed project is self-financed, it may or may not be an early credit candidate.

The last point to make in conclusion, is that while the emissions reductions and energy efficiency savings at the MULTIBRÁS factory level are important, the products (refrigerators) manufactured in these factories, make an even more important contribution in their own right. MULTIBRÁS, and other companies in the Brazilian appliance sector, have made and are achieving very meaningful reductions in the amount of energy refrigerators consumption during their long operating lifetimes with no mandatory governmental program or law. The energy consumed to produce a refrigerator is far less than the energy used during its lifetime. Therefore, any national policy designed to reduce emissions associated with refrigerator production should ensure that capital is devoted to better use, and not focused to an excessive degree on achieving improvements at the factory level at the expense of improvements in the efficiency of the product itself.

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